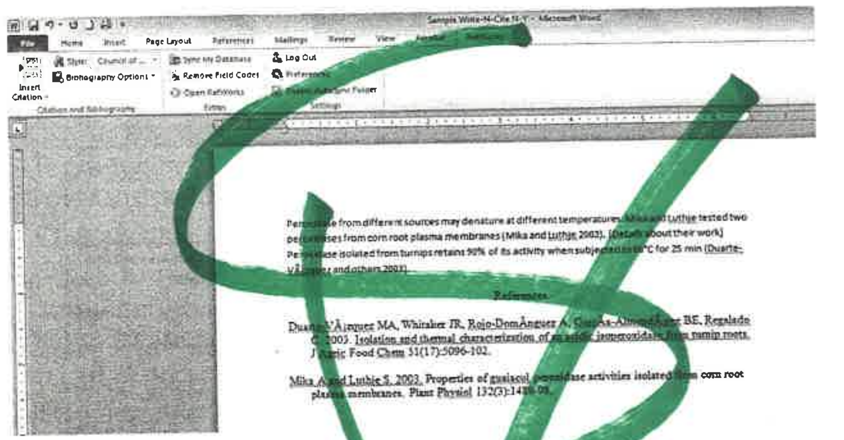

igure 2.12 Final appearance of a sample lab report formatted using the Name-ear system. After clicking **Bibliography Options | Insert Bibliography**, Write-l-Cite generates the end reference list based on the style selected..

8. In your Word document, in-text citations are listed sequentially and the information in the end references is in the correct order (Figure 2.12). Think of the time you'll save by not having to type reference lists!

Reading and Writing Scientific Papers

No matter whether you are a student or are already engaged in a profession, writing is a fact of life. There are many reasons for writing: to express your feelings, to entertain, to communicate information, and to persuade. When you write scientific papers, your primary reasons for writing are to communicate information and to persuade others of the validity of your methods, findings, and conclusions.

Types of Scientific Writing

Scientific writing takes many forms. As an undergraduate biology major, you will be asked to write laboratory reports, answer essay questions on exams, write summaries of journal articles, and do literature surveys on topics of interest. Upperclass students may write a research proposal for honors work, and then complete their project by submitting an honors thesis. Graduate students typically write master's theses and doctoral dissertations and defend their written work with oral presentations. Professors write lectures, letters of recommendation for students, grant proposals, reviews of articles submitted for publication to scientific journals by their colleagues, and evaluations of grant proposals. In business and industry, scientific writing may take the form of progress reports, product descriptions, operating manuals, and sales and marketing material.

Hallmarks of Scientific Writing

What distinguishes scientific writing from other kinds of writing? One difference is the motive. Scientific writing aims to inform rather than to entertain the reader. The reader is typically a fellow scientist who intends to use this information to

- Stay current in his or her field
- Build on what is already known
- Improve a method or adapt a method to a different research question
- Make a process easier or more efficient
- Improve a product

A second difference is the style. Brevity, a standard format, and proper use of grammar and punctuation are the hallmarks of well-written scientific papers. The authors have something important to communicate, and they want to make sure that others understand the significance of their work. Flowery language and "stream of consciousness" prose are not appropriate in scientific writing because they can obscure the writer's intended meaning.

A third difference between scientific and other types of writing is the tone. Scientific writing is factual and objective. The writer presents information without emotion and without editorializing.

Scientific Paper Format

Scientific papers are descriptions of how the scientific method was used to study a problem. They follow a standard format that allows the reader, first, to determine initial interest in the paper, second, to read a summary of the paper to learn more, and, finally, to read the paper itself for all the details. This format is very convenient, because it allows busy people to scan volumes of information in a relatively short time, then spend more time reading only those papers that truly provide the information they need.

Almost all scientific papers are organized as follows:

- Title
- List of authors
- Abstract
- Introduction
- Materials and Methods
- Results

- Discussion
- Acknowledgments
- References

This standard structure is sometimes called the IMRD format. IMRD is an abbreviation of the core sections of a scientific paper.

The **title** is a **short, informative description of the essence of the paper.** It should contain the fewest number of words that accurately convey the content. Readers use the title to determine their initial interest in the paper.

Only the names of **people who played an active role** in designing the experiment, carrying it out, and analyzing the data appear in the **list of authors.**

The **abstract** is a **summary of the entire paper** in 250 words or less. It contains (1) an introduction (scope and purpose), (2) a short description of the methods, (3) results, and (4) conclusions. There are no literature citations or references to figures in the abstract. If the title sounds promising, readers will use the abstract to determine if they are interested in reading the entire paper.

The **introduction** concisely states what motivated the study, how it fits into the existing body of knowledge, and the objectives of the work. The introduction consists of two primary parts:

1. **Background or historical perspective on the topic.** Primary journal articles and review articles, rather than textbooks and newspaper articles, are cited to provide the reader with direct access to the original work. Inconsistencies, unanswered questions, or new questions that resulted from previous work set the stage for the present study.
2. **Statement of objectives of the work.** What were the goals of the present study?

The **Materials and Methods** section describes, in full sentences and well-developed paragraphs, **how the experiment was done.** The author provides sufficient detail to allow another scientist to repeat the experiment. Volume, mass, concentration, growth conditions, temperature, pH, type of microscopy, statistical analyses, and sampling techniques are critical pieces of information that must be included. When and where the work was carried out is important if the study was done in the field (in nature), but is not included if the study was done in a laboratory. Conventional labware and laboratory techniques that are common knowledge (familiar to the audience) are not explained. In some instances, it is appropriate to use references to describe methods.

The **Results** section is **where the findings of the experiment are summarized,** without giving any explanations as to their significance (the "whys" are reserved for the Discussion section). A good Results section has two components:

- A *text*, which forms the body of this section
- Some form of *visual* that helps the reader comprehend the data and get the message faster than from reading a lengthy description

In the **Discussion** section, the **results are interpreted** and possible explanations are given. The author may:

- Summarize the results in a way that supports the conclusions.
- Describe how the results relate to existing knowledge (literature sources).
- Describe inconsistencies in the data. This is preferable to concealing an anomalous result.
- Discuss possible sources of error.
- Describe future extensions of the current work.

In the **Acknowledgments** section of published research articles, the authors recognize technicians, colleagues, and others who have contributed to the research or production of the paper. In addition, the authors acknowledge the organization(s) that provided funding for the work as well as individuals who provided non-commercially available products or organisms.

References list the **outside sources** the authors consulted in preparing the paper. No one has time to return to a state of zero knowledge and rediscover known mechanisms and relationships. That is why scientists rely so heavily on information published by their colleagues. References are typically cited in the Introduction and Discussion sections of a scientific paper, and the procedures given in the Materials and Methods section are often modifications of those in previous work.

Styles for Documenting References

The Council of Science Editors (CSE Manual 2006) recommends the following three systems for documenting references:

Citation-Sequence System. In the *text*, the source of the cited information is provided in an abbreviated form as a superscripted endnote or a number in square brackets or parentheses. On the *references pages* that follow the Discussion section, the sources are listed in **numerical order** and include the full reference.

Name-Year System. In the *text*, the source is given in the form of author(s) and year. On the *references pages* that follow the Discussion section, the references are listed in **alphabetical order** according to the first author's last name.

Citation-Name System. This system is a hybrid of the Citation-Sequence and Name-Year systems. In the *text*, the source of the cited information is provided in an abbreviated form as a superscripted endnote or a number in square brackets or parentheses. On the *references pages* that follow the Discussion section, the references are listed in **alphabetical order** according to the first author's last name. The references are then numbered sequentially.

The Name-Year system has the advantage that people working in the field will know the literature and, on seeing the authors' names, will understand the reference without having to check the reference list. This system is more commonly used and generally is preferred. With the Citation-Sequence and Citation-Name systems, for each reference the reader must turn to the reference list at the end of the paper to gain the same information. Both systems are described in detail on pp. 81–94.

Strategies for Reading Journal Articles

Papers in scientific journals are written by experts in the field. Because you are not yet an expert, you will probably find it difficult to read and understand journal articles. The following strategy may help.

Determine the topic. First, try to determine the topic of the article by reading the title, the abstract, and the first few sentences of the introduction. Based on the keywords, what do you expect the paper to be about?

Acquire background information on the topic. Wikipedia is a good place to start, but it should not be considered an authoritative source for academic work. A better choice may be your textbook, written by scientists and reviewed by other scientists before publication. Because textbook authors generally write for a student audience, not a group of experts, your textbook is likely to be easier to read than the primary literature. See "Strategies for Reading your Textbook" on pp. 37–39 for some ways to read biology textbooks efficiently.

Read the introduction. The introduction is usually easier to follow than the abstract. The first few sentences are aimed at attracting reader interest and the topic is introduced in broad terms. Subsequent sentences narrow down the topic and the specific goals of the paper are presented at the end of this section. Skim the introduction with the following questions in mind:

- Why were the authors interested in this topic or problem?
- What was known about the topic?
- What was unknown or what questions were the authors interested in answering?
- Did the authors propose any hypotheses?
- What are the objectives of the current work?

Read the Results section selectively. Look at the figures and tables to determine what variables were studied. The independent variable (the one the investigator manipulated) is plotted on the *x*-axis, and the dependent variable (the one that changes in response to the independent variable) is plotted on the *y*-axis. Also look for variables in column headings of tables.

Look for a qualitative description of figures and tables in the figure/table caption and in the body of the Results section (text). The caption states the main idea of the visual. The topic sentence of the paragraph in the text does the same. Supporting sentences follow, providing details on what trends or findings the reader should notice in each visual. When you read about the results, some questions to consider are:

- What kind of data are presented: descriptive or numerical?
- If a hypothesis was tested, was there a difference between the controls and the treatment groups?
- Looking at the graphs, what was the relationship between the independent and dependent variables?
- What is the subject of photos and images?

If necessary, reread the introduction to recall the main objectives of the work. Try to understand the big picture before concerning yourself with the details.

Read the Discussion section. A good Discussion section is structured like a triangle, narrow at the top and wide at the base: the information flows from specific to broad (just the opposite of the introduction). In the first few paragraphs, the author interprets the findings of the current work, tying the results directly to the question or problem posed in the introduction. For example, if the goal articulated in the introduction was to determine if hydroxylamine acts as a competitive inhibitor in the peroxidase–hydrogen peroxide reaction, then the reader expects to find the answer to that question in the Discussion section. Each assertion is backed up with experimental evidence.

In the next part of the discussion, the author compares the results described in his/her paper to those in published articles. If the results do not agree, then the author tries to explain why they do not agree. Finally, the author may discuss the implications of the results for our understanding of broader issues and describe future research.

Skim the Materials and Methods section. Scan the subheadings (if present) and the topic sentence of each paragraph to identify the basic approach. Are you familiar with any of the methods? Try to understand the overall concept and do not concern yourself with the details at this stage.

Expect to read the article several times. Even experts may read journal articles several times before they understand the methodology and the implications of the findings. When reading an article for the first time, your mind is exposed to new concepts. When you stop reading, your unconscious mind has time to process these concepts. Then, when you read the article again, a day or a week or a month later, some things that seemed incomprehensible on the first reading may make more sense.

Be an active reader. Instead of using a highlighter, take notes in your own words (see p. 41). Jot down questions where something is unclear. Forcing yourself to engage actively with the words on the page helps you clarify what you know and what you don't know. Active reading is hard work and requires your full attention. Instead of taking the multitasking approach and trying to read, text, email, and socialize with your friends all at the same time, turn off your phone and email and concentrate on the reading for a full hour. You will be surprised at how much more you can accomplish, especially if you set a time limit and plan to do something pleasurable afterwards.

Strategies for Reading Your Textbook

The expectation to read journal articles more than once also applies to reading chapters in your textbook. Repetition is a key ingredient in learning the material. Repetition not only provides you with multiple opportunities to be exposed to the material, but also gives you time to digest it. The basic approach is to read for organization and key concepts first, and then to fill in the details with each subsequent reading. Remember that each time you read the material, you will learn a little more.

The two strategies described here work best with a chapter or section of text no longer than 25–30 pages. The first strategy is proposed by Counselling Services at the University of Victoria, Canada (Palmer-Stone 2001).

1. Take no more than 25 minutes to:
    - Read the chapter title, introduction, and summary (at the end of the chapter, if present)

- Read the headings and subheadings
- Read the chapter title, introduction, summary, headings, and subheadings again
- Skim the topic sentence of each paragraph (usually the first or second sentence)
- Skim italicized or boldfaced words

2. Close your textbook. Take a full 30 minutes to:
   - Write down everything you can remember about what you read in the chapter (make a "mind map"). Each time you come to a dead end, use memory techniques such as associating ideas from your reading to lecture notes or other life experiences; visualizing pages, pictures, or graphs; staring out the window to daydream; and letting your mind go blank.
   - Figure out how all this material is related. Organize it according to what makes sense in your mind, not necessarily according to how it is organized in the textbook. Write down questions and possible contradictions to check on later.
3. Open your textbook. Fill in the blanks in your mind map with a different colored pencil.
4. Read the chapter again, this time normally. Make another mind map.

A second strategy is:

1. Skim the chapter title, headings, and subheadings for an overview of the chapter content. Write down the headings and subheadings in the form of an outline.
2. Look at your outline and ask yourself the following questions:
   - What is the main topic of this chapter?
   - How do each of the headings relate to the topic?
   - How does each subheading relate to its heading?
3. Read each section, paying special attention to the topic sentence of each paragraph. At the end of each section, summarize the content in your own words. Answer the following questions:
   - What's the point?
   - What do I understand?
   - What is confusing?

4. If you read the assigned pages before the lecture, you can pay attention to the lecture content instead of just frantically taking notes. Your instructor may provide PowerPoint slides for the lecture or your textbook may come with a printed lecture notebook or a DVD with the figures. These aids allow you to spend more time listening and less time writing.
5. After the lecture, while the information is still fresh in your mind, reread your notes on your reading. Ask yourself:
   - What topics did the instructor emphasize in lecture? Fill in your lecture notes with details from your textbook.
   - What material do I understand better now?
   - What questions remain?

Study Groups

If you have read the material several times, taken notes, and listened attentively in lecture, but still have questions, talk about the material with your classmates. Small study groups are one reason why students who choose to major in the sciences persist in the sciences, rather than switching to a nonscience major (Light 2001).

What are some benefits of participating in small study groups? One benefit is the comfort level. You may be more likely to talk about problems when you are among your peers; after all, they are not the ones who assign your grade. Secondly, when a group is composed of peers with a similar knowledge base, group members speak the same language. Your instructor speaks a different language, because he or she has already struggled to master the material. When you communicate with your classmates, you verbalize your ideas at a level that is appropriate for your audience of peers. Finally, collaborative learning reflects the way scientists exchange information and share findings in the real world. A spirit of camaraderie develops when people work together toward a common goal. The prospect of learning difficult subject matter is no longer so daunting when you have support from a small group of like-minded individuals. The hard work may even be fun when there is good group chemistry.

Group study is not a substitute for studying alone, however. You must hold yourself accountable for reading the material, taking notes, and figuring out what you do not understand before you meet with your group. If you have not struggled to understand the material yourself, you are not in a position to help a classmate.

Plagiarism

Plagiarism is using someone else's ideas or work without acknowledging the source. Plagiarism is ethically wrong and demonstrates a lack of respect for members of your academic community (faculty and fellow students) and the scientific community in general. Many instructors are now using plagiarism checking services such as Turnitin® and SafeAssign™ by Blackboard to discourage *intentional* plagiarism, such as "borrowing" portions of another student's work, recycling lab reports from previous years, and buying papers on the Internet. Plagiarists who are caught can expect to receive at a minimum a failing grade on the assignment and close scrutiny in subsequent work. Plagiarism may also be cause for expulsion from school.

Many cases of plagiarism are *unintentional*, however, and stem from issues such as

- Failure to understand what kind of information must be acknowledged
- Failure to reference the original material properly
- Failure to understand the subject matter clearly

Information that does not have to be acknowledged

General information that is obtained from sources such as news media, textbooks, and encyclopedias does not have to be acknowledged.

> EXAMPLE: Most of the ATP in eukaryotic cells is produced in the mitochondria.

Information that is common knowledge for your audience does not have to be acknowledged. In an introductory course in cell and molecular biology, for example, students would be expected to know that ATP synthase is the enzyme that produces ATP through oxidative phosphorylation.

> EXAMPLE: ATP is synthesized when protons flow down their electrochemical gradient through a channel in ATP synthase.

Information that has to be acknowledged

Information that falls into any of the following categories must be acknowledged:

- Information that is not widely known
- Controversial statements, opinions, or other people's conclusions
- Pictures or illustrations that you use but did not produce
- Statistics or formulas used in someone else's work
- Direct quotations

Paraphrasing the source text

Direct quotations are used in the humanities, but not in scientific papers. This idiosyncrasy of technical writing requires you to paraphrase the information in the source document. Paraphrasing—using your own words to express someone else's ideas—requires considerable thought and effort on your part. Not only do you have to have sufficient knowledge about the subject, you have to feel comfortable using the vocabulary. Read your textbook and other secondary sources, discuss the topic in your study group, or ask your instructor for clarification. A lot of groundwork has to be done before you can even begin to read a journal article, let alone paraphrase information it contains.

When you have acquired this background information, you are ready to tackle the content. Accept the fact that comprehension is an ongoing process in which you will read the source text, process the information you've read, read the text again, and process some more. When you are comfortable with the content, take notes on the important points, following the collective advice of Hofmann (2010), Lannon and Gurak (2011), McMillan (2012), Pechenik (2012), and other authorities on scientific writing:

- Don't take notes until you have read the source text at least twice and are fairly confident that you have sufficient background on the subject.
- Retain key words.
- Don't use full sentences.
- Use your own words and write in your own style.
- Distinguish your own ideas and questions from those of the source text (e.g., "Me: Applies only to prokaryotes?").
- Use quotation marks to indicate exact or similar wording. Keep in mind that you will have to put the information into your own words if you use the information in your paper.
- Don't cite out of context. Preserve the author's original meaning.
- Fully document the source for later listing in the end references.

Faulty note-taking practices, particularly those that involve copying large portions of the original text, are likely to result in unintentional plagiarism. Beware of the pitfalls illustrated in Table 3.1. To avoid plagiarism, write in your own words and cite the source. For practice in identifying and avoiding plagiarism, take Frick's (2004) excellent online plagiarism tutorial. Read your institution's policies on academic responsibility, consult with professionals at your school's writing center, and ask your instructor for help when in doubt.

The Benefits of Learning to Write Scientific Papers

Why is it valuable to learn how to write scientific papers? First, scientific writing is a systematic approach to describing a problem. By writing what you know (and what you do not know) about the problem, it is often possible to identify gaps in your own knowledge.

Second, the scientific method is a logical approach to answering questions. It involves coming up with a tentative solution, gathering information to become more knowledgeable about the topic, evaluating the reliability of the information, testing and analyzing the data, and arriving at a reasonable conclusion. This approach can be applied to many situations in your life, from deciding to which graduate school to apply to choosing your next cell phone or another consumer product.

Third, when you learn to write lab reports, you are investing in your future. Publications in the sciences are affirmation from your colleagues that your work has merit; you have been accepted into the community of experts in your field. Even if your career path is not in the sciences, scientific writing is very logical and organized, characteristics appreciated by busy people everywhere.

Credibility and Reputation

The credibility and reputation of scientists are established primarily by their ability to communicate effectively through their written reports. Poorly written papers, regardless of the importance of the content, may not get published if the reviewers do not understand what the writer intended to say.

You should think about your reputation even as a student. When you write your laboratory reports in an accepted, concise, and accurate manner, your instructor knows that you are serious about your work. Your instructor appreciates not only the time and effort required to understand the subject matter, but also your willingness to write according to the standards of the profession.

Model Papers

Before writing your first laboratory report, go to the library and take a look at some biology journals such as *American Journal of Botany*, *Ecology*, *The EMBO Journal*, *Journal of Biological Chemistry*, *Journal of Molecular Biology*, and *Marine Biology*. Photocopy one or two journal articles that interest you so you can refer to them for format questions.

TABLE 3.1 Examples of plagiarism

Original Text

F_1 extends from the membrane, with the α and β subunits alternating around a central subunit γ. ATP synthesis occurs alternately in different β subunits, the cooperative tight binding of ADP + P_i at one catalytic site being coupled to ATP release at a second. The differences in binding affinities appear to be caused by rotation of the γ subunit in the center of the α3 β3 hexamer.

Plagiarized Text	Reason
According to Fillingame (1997), F1 extends from the membrane, with the α and β subunits alternating around a central subunit γ. ATP synthesis occurs alternately in different β subunits, the cooperative tight binding of ADP + P_i at one catalytic site being coupled to ATP release at a second. The differences in binding affinities appear to be caused by rotation of the γ subunit in the center of the α3 β3 hexamer.	The author's actual words were used without quotation marks or indenting the citation. Because direct quotations are not used in scientific papers, it is imperative that you paraphrase. Using the original text is plagiarism even when the source is cited.
F_1 consists of α and β subunits alternating around a central subunit γ. In the β subunits, tight binding of ADP + P_i occurs at one catalytic site and ATP is released at a second. The different binding affinities may be caused by rotation of the γ subunit in the center (Fillingame 1997).	The basic sentence structure of the original text was maintained. A few words were omitted or changed, but the text is still highly similar to the original.
ATP synthase consists of a transmembrane protein (F_o), a central shaft (γ), and an F_1 head made up of α and β subunits. As protons enter F_o, the shaft rotates, changing the conformation of the β subunits, allowing ADP and P_i to bind and be released as ATP.	The text was paraphrased, but the source of the information was not cited.

Source: From Fillingame RH. 1997. Coupling H^+ transport and ATP synthesis in F_1F_o-ATP synthases: glimpses of interacting parts in a dynamic molecular machine. *The Journal of Experimental Biology* [Internet] [cited 2012 Oct 30]; 200: 217–224. Available from: http://jeb.biologists.org/content/200/2/217.full.pdf+html

Almost all journals devote one page or more to "Instructions to Authors," in which specific information is conveyed regarding length of the manuscript, general format, figures, conventions, references, and so on. Skim this section to get an idea of what journal editors expect from scientists who wish to have their work published.

Because most beginning biology students find journal articles hard to read, a sample student laboratory report is given in Chapter 6. Read the comments in the margins as you peruse the report to familiarize yourself with the basics of scientific paper format and content, as well as purpose, audience, and tone.

Chapter 4

Step-by-Step Instructions for Preparing a Laboratory Report or Scientific Paper

In order to prepare a well-written laboratory report according to accepted conventions, the following skills are required:

- A solid command of the English language
- An understanding of the scientific method
- An understanding of scientific concepts and terminology
- Advanced word processing skills
- Knowledge of computer graphing software
- The ability to read and evaluate journal articles
- The ability to search the primary literature efficiently
- The ability to evaluate the reliability of Internet sources

If you are a first- or second-year college student, it is unlikely that you possess all of these skills when you are asked to write your first laboratory report. Don't worry. The instructions in this chapter will guide you through the steps involved in preparing the first draft of a laboratory report. Revision is addressed in the next chapter, and the Appendices will help you with word processing and graphing tasks.

Timetable

Preparing a laboratory report or scientific paper is hard work. It will take much more time than you expect. Writing the first draft is only the first step. You must also allow time for editing and proofreading (revision). If you work on your paper in stages, the final product will be much better than if you try to do everything at the last minute.