How to read a scientific paper

Modified from John W. Little and Roy Parker--University of Arizona

Paper organization:

In most scientific journals, scientific papers follow a standard format. They are divided into several sections, and each section serves a specific purpose in the paper. We first describe the standard format, then some variations on that format.

1) A paper begins with a short **Summary** or **Abstract**. Generally, it gives a brief background to the topic; describes concisely the major findings of the paper; and relates these findings to the field of study. As will be seen, this logical order is also that of the paper as a whole.

2) The next section of the paper is the **Introduction**. In many journals this section is not given a title. As its name implies, this section presents the background knowledge necessary for the reader to understand why the findings of the paper are an advance on the knowledge in the field. Typically, the Introduction describes first the accepted state of knowledge in a specialized field; then it focuses more specifically on a particular aspect, usually describing a finding or set of findings that led directly to the work described in the paper. If the authors are testing a hypothesis, the source of that hypothesis is spelled out, findings are given with which it is consistent, and one or more predictions are given. In many papers, one or several major conclusions of the paper are presented at the end of this section, so that the reader knows the major answers to the questions just posed. Papers more descriptive or comparative in nature may begin with an introduction to an area which interests the authors, or the need for a broader database.

3) The next section of most papers is the **Materials and Methods**. In some journals this section is the last one. Its purpose is to describe the materials used in the experiments and the methods by which the experiments were carried out. In principle, this description should be detailed enough to allow other researchers to replicate the work. In practice, these descriptions are often highly compressed, and they often refer back to previous papers by the authors.

4) The third section is usually **Results**. This section describes the experiments and the reasons they were done. Generally, the logic of the Results section follows directly from that of the Introduction. That is, the Introduction poses the questions addressed in the early part of Results. Beyond this point, the organization of Results differs from one paper to another. In some papers, the results are presented without extensive discussion, which is reserved for the following section. This is appropriate when the data in the early parts do not need to be interpreted extensively to understand why the later experiments were done. In other papers, results are given, and then they are interpreted, perhaps taken together with other findings not in the paper, so as to give the logical basis for later experiments.

5) The fourth section is the **Discussion**. This section serves several purposes. First, the data in the paper are interpreted; that is, they are analyzed to show what the authors believe the data show. Any limitations to the interpretations should be acknowledged, and fact should clearly be separated from speculation. Second, the findings of the paper are related to other findings in the field. This serves to show how the findings contribute to knowledge, or correct the errors of previous work. As stated, some of these logical arguments are often found in the Results when it is necessary to clarify why later experiments were carried out. Although you might argue that in this case the discussion material should be presented in the Introduction, more often you cannot grasp its significance until the first part of Results is given.

6) Finally, papers usually have a short **Acknowledgements** section (**look for funding source(s)**), in which various contributions of other workers are recognized, followed by a **Reference** list giving references to papers and other works cited in the text.

Conflicts of interest are often spelled out in this section as well as the exact contribution of the authors (due to recent problems regarding scientific fraud).

7) Papers also contain several **Figures** and **Tables**. These contain data described in the paper. The figures and tables also have legends, whose purpose is to give details of the particular experiment or experiments shown there. Typically, if a procedure is used only once in a paper, these details are described in Materials and Methods, and the Figure or Table legend refers back to that description. If a procedure is used repeatedly, however, a general description is given in Materials and Methods, and the details for a particular experiment are given in the Table or Figure legend.

Reading the paper:

1) **Read the title and the abstract**. Although it is tempting to read the paper straight through as you would do with most text, it is more efficient to organize the way you read. Generally, you first read the Abstract in order to understand the major points of the work. The extent of background assumed by different authors, and allowed by the journal, also varies as just discussed.

One extremely useful habit in reading a paper is to read the Title and the Abstract and, before going on, review in your mind what you know about the topic. This serves several purposes. First, it clarifies whether you in fact know enough background to appreciate the paper. If not, you might choose to read the background in a review or textbook, as appropriate.

Identify key words (often listed at the bottom of the first page). These words and concepts will be important to the paper. Do you understand these words?

Look at author affiliations (University, biotech, pharm, nonprofit) and funding sources. A drug study performed by or funded by a company that has positive results would benefit that company. **Be skeptical, but not cynical!**

2) **Read the introduction, results, and discussion.** The materials and methods should be read as needed to understand the results section, but does not have to be read in the order in which it appears.

Evaluating the paper (the SIX questions):

1) What questions does the paper address? ***Put another way, why was the study performed?***

In a well-written paper, as described above, the Introduction generally goes from the general to the specific, eventually framing a question or set of questions, so this is a good starting place. Sometimes, the question also is stated in the abstract. In addition, the results of experiments usually raise additional questions, which the authors may attempt to answer. These questions usually become evident only in the Results section.

The author(s) should explicitly state a hypothesis (or hypotheses) that they will test in reference to the problem they have identified. Sometimes this is done implicitly and is left to the reader to figure out.

2) What are the main conclusions of the paper?

This question can often be answered in a preliminary way by studying the abstract of the paper. Here the authors highlight what they think are the key points. This is not enough, because abstracts often have severe space constraints, but it can serve as a starting point. Still, you need to read the paper with this question in mind. Often the conclusions will be spelled out in the discussion.

3) What evidence supports those conclusions?

Generally, you can get a pretty good idea about this from the Results section. The description of the findings points to the relevant tables and figures. This is easiest when there is one primary experiment to support a point. However, it is often the case that several different experiments or approaches combine to support a particular conclusion. For example, the first experiment might have several possible interpretations, and the later ones are designed to distinguish among these.

In the ideal case, the Discussion begins with a section of the form "Three lines of evidence provide support for the conclusion that... First, ...Second,... etc." However, difficulties can arise when the paper is poorly written (see above). The authors often do not present a concise summary of this type, leaving you to make it yourself. A skeptic might argue that in such cases the logical structure of the argument is weak and is omitted on purpose! In any case, you need to be sure that you understand the relationship between the data and the conclusions.

4) Do the data actually support the conclusions? This may be difficult if you are unfamiliar with the research…

One major advantage of doing this is that it helps you to evaluate whether the conclusion is sound. If we assume for the moment that the data are believable (see next section), it still might be the case that the data do not actually support the conclusion the authors wish to reach. There are at least two different ways this can happen:

i. The logical connection between the data and the interpretation is not sound

ii. There might be other interpretations that might be consistent with the data.

One important aspect to look for is whether the authors take multiple approaches to answering a question. Do they have multiple lines of evidence, from different directions, supporting their conclusions? If there is only one line of evidence, it is more likely that it could be interpreted in a different way; multiple approaches make the argument more persuasive.

Another thing to look for is implicit or hidden assumptions used by the authors in interpreting their data. This can be hard to do, unless you understand the field thoroughly.

5) What is the quality of the evidence? This may be very difficult if you are not familiar with the methodology (did they choose the right experiment, controls, etc…)

This is the hardest question to answer, for novices and experts alike. At the same time, it is one of the most important skills to learn as a young scientist. It involves a major reorientation from being a relatively passive consumer of information and ideas to an active producer and critical evaluator of them. This is not easy and takes years to master. Beginning scientists often wonder, "Who am I to question these authorities? After all the paper was published in a top journal, so the authors must have a high standing, and the work must have received a critical review by experts." Unfortunately, that's not always the case. In any case, developing your

ability to evaluate evidence is one of the hardest and most important aspects of learning to be a critical scientist and reader.

First, you need to understand thoroughly the methods used in the experiments.

Second, you need to know the **limitations** of the methodology. Every method has limitations, and if the experiments are not done correctly they can't be interpreted.

Third, importantly, you need to distinguish between what the data show and what the authors **say** they show.

Fourth, it is often helpful to look at the original journal, or its electronic counterpart, instead of a photocopy.

Fifth, you should ask if the proper controls are present. Controls tell us that nature is behaving the way we expect it to under the conditions of the experiment. If the controls are missing, it is harder to be confident that the results really show what is happening in the experiment. You should try to develop the habit of asking "where are the controls?" and looking for them.

6) Why are the conclusions important?

Do the conclusions make a significant advance in our knowledge? Do they lead to new insights, or even new research directions?

Again, answering these questions MAY require that you understand the field relatively well.

Each assignment is due by the start of class on the scheduled discussion date. Assignments must be typed using **12 point Arial font** and **answers are limited to 250 words for each question**. Assignments must be **submitted as word documents via the D2L assignment submission folder**. Each assignment is worth **20 points**.

1) What question(s) does the paper address? *Put another way, why was the study performed?* In addition, what is the hypothesis? If multiple hypotheses are provided, you only need to list one. Do so in a single, succinct sentence.

2) What are the main conclusions of the paper?

6) Why are the conclusions important?

Grading Rubric for Literature Assignment					
Spelling/Grammar/ Formatting	**No errors/all sections present**	**Minimal errors**	**Sections absent, multiple grammar/spelling errors**	**Possible**	**Total**
	5	**2.5**	**0**	**5**	
Problem and hypothesis	**Key problem identified and thoroughly discussed including background, hypothesis stated**	**Close…**	**Not properly identified, background not provided, no hypothesis provided**		
	5	**2.5**	**0**	**5**	
Main Conclusion(s)	**Salient conclusions summarized**	**Close…**	**Conclusions improperly summarized**		
	5	**2.5**	**0**	**5**	
Importance of Conclusion(s)	**Conclusions given context, "big picture" discussed**	**Limited discussion**	**Absent or simple restatement of conclusions**		
	5	**2.5**	**0**	**5**	
				20	