How to Read a Scientific Research Paper--
a four-step guide for students *and for faculty*

Ann McNeal, School of Natural Science, Hampshire College, Amherst MA 01002

Reading research papers ("primary articles") is partly a matter of experience and skill, and partly learning the specific vocabulary of a field. First of all, DON'T PANIC! If you approach it step by step, even an impossible-looking paper can be understood.

1. **Skimming.** Skim the paper quickly, noting basics like headings, figures and the like. This takes just a few minutes. You're not trying to understand it yet, but just to get an overview.

2. **Vocabulary.** Go through the paper word by word and line by line, underlining or highlighting **every word and phrase** you don't understand. Don't worry if there are a lot of underlinings; you're still not trying to make sense of the article.

Now you have several things you might do with these vocabulary and concept questions, depending upon the kind of question each is. You can

a. **Look up simple words and phrases**. Often the question is simply vocabulary--what's a *lateral malleolus*, or a *christa*, or the *semilunar valve*. A **medical** or **biological dictionary** is a good place to look for definitions. A **textbook of physiology or anatomy** may be a good source, because it give more complete explanations. Your **ordinary shelf dictionary** is **not** a good source, because the definitions may not be precise enough or may not reflect the way in which scientists use a word (for example "efficiency" has a common definition, but the physical definition is much more restricted.)
b. **Get an understanding from the context in which it is used.** Often words that are used to describe the procedures used in an experiment can be understood from the context, and may be very specific to the paper you are reading. Examples are the "lithium-free control group" in a rat experiment or the "carotene extraction procedure" in a biochemical experiment. Of course, you should be careful when deciding that you understand a word from its context, because it might not mean what you think.
c. **Flag this phrase as belonging to one of the major concepts of the paper**--it's bigger than a vocabulary question. For example, a paper about diet and cancer might refer to "risk reduction," which you would need to understand in context and in some depth.

3. **Comprehension, section by section.** Try to deal with all the words and phrases, although a few technical terms in the Methods section might remain. Now go back and read the whole paper, section by section, for comprehension.

In the **Introduction**, note how the context is set. What larger question is this a part of? The author should summarize and comment on previous research, and you should distinguish between previous research and the actual current study. What is the hypothesis of the paper and the ways this will be tested?

In the **Methods**, try to get a clear picture of what was done at each step. What was actually measured? It is a good idea to make an outline and/or sketch of the procedures and instruments. Keep notes of your questions; some of them may be simply technical, but others may point to more fundamental considerations that you will use for reflection and criticism below.

In **Results** look carefully at the figures and tables, as they are the heart of most papers. A scientist will often read the figures and tables before deciding whether it is worthwhile to read the rest of the article! What does it mean to "understand" a figure? You understand a figure when you can redraw it and explain it in plain English words.

The **Discussion** contains the conclusions that the author would like to draw from the data. In some papers, this section has a lot of interpretation and is very important. In any case, this is usually where the author reflects on the work and its meaning in relation to other findings and to the field in general.

4. **Reflection and criticism.** After you understand the article and can summarize it, then you can return to broader questions and draw your own conclusions. It is very useful to keep track of your questions as you go along, returning to see whether they have been answered. Often, the simple questions may contain the seeds of very deep thoughts about the work--for example, "Why did the authors use a questionnaire at the end of the month to find out about premenstrual tension? Wouldn't subjects forget or have trouble recalling?"

Here are some questions that may be useful in analyzing various kinds of research papers:

Introduction:

What is the overall purpose of the research?

How does the research fit into the context of its field? Is it, for example, attempting to settle a controversy? show the validity of a new technique? open up a new field of inquiry?

Do you agree with the author's rationale for studying the question in this way?

Methods:

Were the measurements appropriate for the questions the researcher was approaching?

Often, researchers need to use "indicators" because they cannot measure something directly--for example, using babies' birthweight to indicate nutritional status. Were the measures in this research clearly related to the variables in which the researchers (or you) were interested?

If human subjects were studied, do they fairly represent the populations under study?

Results

What is the one major finding?

Were enough of the data presented so that you feel you can judge for yourself how the experiment turned out?

Did you see patterns or trends in the data that the author did not mention? Were there problems that were not addressed?

Discussion

Do you agree with the conclusions drawn from the data?

Are these conclusions over-generalized or appropriately careful?

Are there other factors that could have influenced, or accounted for, the results?

What further experiments would you think of, to continue the research or to answer remaining questions?

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Teacher's Guide to reading primary literature

Ann McNeal, School of Natural Science, Hampshire College, Amherst MA 01002
>amcneal@hampshire.edu>

There are many advantages to having undergraduates read primary literature (Epstein, 1972):

- Articles have a vividness that is seldom found in a text, so students get excited by them.
- Articles lend themselves to critical, analytical thinking.
- Students feel smart and powerful when they read original sources.
- Articles reveal the scientific process far better than secondary sources.

It is important to choose articles that are appropriate for your students, looking at **conceptual depth, vocabulary, and accessibility of the experimental and statistical techniques**. Of these considerations, **vocabulary** is perhaps the least important, especially if you follow the suggestions below for introducing students to the new words. It is amazing what students can and do read, if they are given the tools to do so. **Conceptual depth** refers to the difficulty of the concepts important to the article. For example, an article on transcriptional factors in white blood cells requires students to understand some molecular biology. Such an article could be perfect for a cell biology course, but might be too advanced for basic biology. In addition to the difficulty of the main ideas addressed, the article may present some **experimental and statistical techniques** that are just too hard to grasp. For example, articles on research in epidemiology, such as the relationship of heart attacks to diet, are often wonderfully accessible--except when the authors use logistical analysis. Or an article on evolutionary relationships among protein molecules might be quite readable--except for the PCR techniques. In both these cases, you could decide to use the article anyway, if you have carefully figured out how to present the difficult techniques in a reasonably palatable way.

In preparing your students to read articles for the first time, you will usually need to allocate a good amount of class time for the first article, but this experience should prepare them to be able to be a lot more independent in the future. This is the protocol we have found successful for first-time readers of research articles. (Woodhull-McNeal, 1989)

- **A. Assignment 1.** When you first assign the article, talk it up, saying how powerful students will feel when they can read the original literature and how exciting it is to read the papers scientists write for one another. Acknowledge that it will not be easy, but reassure students that you have a system that will make it all right. Briefly outline the four steps:

  1. Skimming,

2. Vocabulary,
3. Comprehension,
4. Reflection and analysis.

All students need to have copies of the paper so that they may mark it up freely. Send them away with the first assignment to do step 1 (skimming) and part of step 2 (vocabulary). What they should do is to underline or highlight **every word and phrase** they don't understand. The next class period will be devoted to giving them an understanding of the vocabulary.

B. First class discussion--vocabulary. Plan to **spend the entire class period defining terms they do not understand.** It seems time-consuming, but in our experience it is completely worthwhile. Ask students to contribute words or phrases to be defined. Encourage everyone to name at least one term that needs defining--this helps to put them all on a more equal footing. (If students are asked to go and look up terms on this first paper, unless they are all at a high level, the exercise tends to split them further, with the more advanced students outstripping the others.) It is useful to write all terms on the board first, as the students name them, and to organize them by category (e.g., technique words from Methods, anatomical terms, chemicals). After most of the words have been listed, you may want to ask them about some others that they may have ignored. Then choose whatever order seems best to you (doing simple terms first often is helpful) and define, define, explain, explain. Remember, you aren't explaining the paper, just the vocabulary.

C. Second assignment--comprehension. The next assignment is to read the paper for comprehension. At this point, you might want to assign students to answer some questions on the paper as well. The guidelines for students are as follows:

In the **Introduction**, note the overall context--

- what larger question is this a part of?
- the author's summary and comments on previous research,
- the hypothesis of the paper and the ways this will be tested.

In the **Methods**, try to get a clear picture of what was done at each step. What was actually measured? It is a good idea to make an outline and/or sketch of the procedures and instruments. Keep notes of your questions; some of them may be simply technical, but others may point to more fundamental considerations that you will use for reflection and criticism below.

In **Results** look carefully at the figures and tables, as they are the heart of most papers. A scientist will often read the figures and tables before deciding whether it is worthwhile to read the rest of the article! What does it mean to "understand" a figure? You understand a figure when you can redraw it and explain it in plain English words.

The **Discussion** contains the conclusions that the author would like to draw from the data. In some papers, this section has a lot of interpretation and is very important. In any case, this is usually where the author reflects on the work and its meaning in relation to other findings and to the field in general.

D. Second discussion --comprehension. The second discussion can focus on comprehension of each section of the article. Students often avoid working with the figures and tables. Instead of whole-class

discussions of these, you might want to assign small groups of the students to spend ten minutes in class redrawing figures and tables and preparing to explain them to everyone else.

E. Third assignment--reflection and analysis. To integrate their knowledge and think about the article more critically, students usually need a third exposure. The student guidelines for this reading are as follows:

After you understand the article and can summarize it, then you can return to broader questions and draw your own conclusions. It is very useful to keep track of your questions as you go along, returning to see whether they have been answered. Often, the simple questions may contain the seeds of very deep thoughts about the work--for example, "Why did the authors use a questionnaire at the end of the month to find out about premenstrual tension? Wouldn't subjects forget or have trouble recalling?"

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Discussion

- Do you agree with the conclusions drawn from the data?
- Are these conclusions over-generalized or appropriately careful?
- Are there other factors that could have influenced, or accounted for, the results?
- What further experiments would you think of, to continue the research or to answer remaining questions?

F. Third discussion--reflection and analysis. This is the opportunity to set the article in a larger

context, to understand its relation to text material, and to encourage students to think beyond the outlines of the article, examining other factors that may not have been explored in the research. The questions above are a good basis for discussion. You may wish to break students into small groups to reflect on particular questions and present their ideas to the larger group. This discussion may take less than a full class period.

If students are advanced or if the article is relatively easy for them, you may combine the second and third assignments and discussions, but we have found that allowing ample time is key to allowing all students to reach a good level of understanding.

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