How to read scientific papers

You will be reading several papers from the primary literature for this class. You will be expected to be able to critically evaluate what you have read because this is an important skill for you to develop as a scientist. This handout is designed to help you approach this task.

My goal in having you read these papers is for you to understand how scientific information is generated and to improve your ability to critically evaluate scientific evidence. *Critical evaluation does not necessarily mean a negative evaluation*; rather, it should be one that recognizes both the strengths and weaknesses of the paper. Always keep in mind that the papers you read are written by normal people who don't have all of the answers or all of the time and money needed to discover them; and they sometimes make mistakes. Learn to evaluate their work as you would that of your peers.

Scientific literature comes in two basic forms: primary and secondary literature. Almost all of the papers you will be reading are from the primary literature: papers that report original research. The secondary literature consists of papers and books (including your text book) that attempt to review, integrate, and summarize topics covered in the primary literature.

Scientific papers are usually written in a fairly standard format and style. Rarely are they written in a fashion that will make you trade your novel for them, but their consistent format and concise style makes it easy for experienced readers to quickly locate information they are interested in. Unfortunately, few scientists receive any formal training on how to write well, so the quality of scientific writing is quite variable.

Scientific papers in the primary literature typically contain 5 sections:

Abstract: This section provides a brief summary of the material in the paper: the questions, general approach used, results, interpretation, and conclusions.

Introduction: Describes the general subject, reviews past work, and introduces the present study. It provides context for the questions asked in the study.

Methods: Describes the study system (organisms, locations, time period) and techniques used (observational and/or experimental design and statistical tests). This section explains how the author(s) tried to answer their questions.

Results: Presents results (data), describing them in prose and, normally, also in figures and tables.

Discussion: Interprets the results and relates them to previous work and relevant theory. Should provide answers to the original questions raised by the author(s) in the introduction. Should explain how the research described has advanced our understanding of the subject.

So basically, the four main sections answer the questions: Why, How, What, and Who Cares? The abstract lets you decide quickly whether you even want to read the paper at all. You will encounter stylistic variations among journals on the standard format outlined above, but all of the information will still be there, though the level of detail does vary.

After reading a paper, you should be able to answer the following questions:

1. What questions are being asked? Are there other hypotheses that could explain the same phenomena? Are some hypotheses exclusive of others?
2. What methods were used to answer the main questions? Can you think of better ways to answer the same questions? (Be realistic when you think about that – researchers have limited supplies of time and money. Could you do a better job than the author(s) if you spent as much time and money as they did?)
3. Does the interpretation of the data seem fair and accurate?
4. Are the conclusions justified by the data? Were the original questions answered?
5. What are the implications of the results for general issues in this field?
6. Are there further studies suggested by this work that might help to clarify things?

I will expect you to be able to answer these questions during our class. Here are some practical suggestions to help you get the most out of the papers:

1. Read each paper at least twice. Initially, read it quickly to get a general understanding of the question, methods, results, and supposed significance of the paper. Your second (and subsequent) reading(s) should be from a critical and skeptical perspective. For me, it often takes 3 or more readings to completely understand everything in a paper.
2. Read the sections of a paper in whichever order works best for you. You don't have to start at the beginning and read to the end. Some people like to read the abstract and then the discussion to see where the argument is headed. Others like to look and the data first – the graphs and tables – to get a feeling for the results, which then helps them comprehend the story in the text. Try different approaches and find out what works best for you.
3. Pay special attention to the data, especially the tables and graphs. The data are the backbone of the paper and you need to understand them. Compare your impression of them with the author's interpretation of them. Do you agree?
4. Make comments. Highlight or underline the parts that you think are important. Write notes in the margin. Use a question mark to note things that you don't understand or disagree with.
5. Read critically. What assumptions does the author make? Are they valid? Can the techniques used really answer the questions the author poses? Are the arguments logical? Are possible alternatives considered?
6. Don't get bogged down. A scientific paper should tell a story and the plot is more important than the details. Skip difficult parts to avoid loosing the story line. Come back to them later and see if you can reason them out, and if you can't, ask about them during seminar – other students are probably confused, too.
7. For the purposes of this class, assume that the statistical analyses were appropriate and performed correctly. (If you have a strong background in statistics, you are

welcome to question the analyses, but if not, I don't want you to waste time worrying about the stats.)

8. Find enough time to thoroughly read each paper at least a couple of times.