

How to read and understand a scientific paper: a guide for non-scientists

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From vaccinations to climate change, getting science wrong has very real

*consequences. But journal articles, a primary way science is communicated in academia, are a different format to newspaper articles or blogs and require a level of skill and undoubtedly a greater amount of patience. Here **Jennifer Raff** has prepared a helpful guide for non-scientists on how to read a scientific paper. These steps and tips will be useful to anyone interested in the presentation of scientific findings and raise important points for scientists to consider with their own writing practice.*

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My post, [The truth about vaccinations: Your physician knows more than the University of Google](#) sparked a very lively discussion, with comments from several people trying to persuade me (and the other readers) that *their* paper disproved everything that I'd been

saying. While I encourage you to go read the comments and contribute your own, here I want to focus on the much larger issue that this debate raised: what constitutes scientific authority?

It's not just a fun academic problem. Getting the science wrong has very real consequences. For example, when a community doesn't vaccinate children because they're afraid of "toxins" and think that prayer (or diet, exercise, and "clean living") is enough to prevent infection, outbreaks happen.

| "Be skeptical. But when you get proof, accept proof." –Michael Specter

What constitutes enough proof? Obviously everyone has a different answer to that question. But to form a truly educated opinion on a scientific subject, you need to become familiar with current research in that field. And to do that, you have to read the "primary research literature" (often just called "the literature"). You might have tried to read scientific papers before and been frustrated by the dense, stilted writing and the unfamiliar jargon. I remember feeling this way! Reading and understanding research papers is a skill which every single doctor and scientist has had to learn during graduate school. You can learn it too, but like any skill it takes patience and practice.

I want to help people become more scientifically literate, so I wrote this guide for how a layperson can approach reading and understanding a scientific research paper. It's appropriate for someone who has no background whatsoever in science or medicine, and based on the assumption that he or she is doing this for the purpose of getting a *basic* understanding of a paper and deciding whether or not it's a reputable study.

The type of scientific paper I'm discussing here is referred to as a **primary research article**. It's a peer-reviewed report of new research on a specific question (or questions). Another useful type of publication is a **review article**. Review articles are also peer-reviewed, and don't present new information, but summarize multiple primary research articles, to give a sense of the consensus, debates, and unanswered questions within a field. (I'm not going to say much more about them here, but be cautious about which review articles you read. Remember that they are only a snapshot of the research at the time they are published. A review article on, say, genome-wide association studies from 2001 is not going to be very informative in 2013. So much research has been done in the intervening years that the field has changed considerably).

Before you begin: some general advice

Reading a scientific paper is a completely different process than reading an article about science in a blog or newspaper. Not only do you read the sections in a different order than they're presented, but you also have to take notes, read it multiple times, and probably go

look up other papers for some of the details. Reading a single paper may take you a very long time at first. Be patient with yourself. The process will go much faster as you gain experience.

Most primary research papers will be divided into the following sections: Abstract, Introduction, Methods, Results, and Conclusions/Interpretations/Discussion. The order will depend on which journal it's published in. Some journals have additional files (called Supplementary Online Information) which contain important details of the research, but are published online instead of in the article itself (make sure you don't skip these files).

Before you begin reading, take note of the authors and their institutional affiliations. Some institutions (e.g. University of Texas) are well-respected; others (e.g. [the Discovery Institute](#)) may appear to be legitimate research institutions but are actually agenda-driven. *Tip: google "Discovery Institute" to see why you don't want to use it as a scientific authority on evolutionary theory.*

Also take note of the journal in which it's published. Reputable (biomedical) journals will be indexed by [Pubmed](#). [EDIT: Several people have reminded me that non-biomedical journals won't be on Pubmed, and they're absolutely correct! (thanks for catching that, I apologize for being sloppy here). Check out [Web of Science](#) for a more complete index of science journals. And please feel free to share other resources in the comments!] Beware of [questionable journals](#).

As you read, write down **every single word** that you don't understand. You're going to have to look them all up (yes, every one. I know it's a total pain. But you won't understand the paper if you don't understand the vocabulary. Scientific words have extremely precise meanings).

How to read a scientific paper: a guide for non-scientists

1. Read the introduction (not the abstract)
2. Identify the BIG QUESTION
3. Summarize the background in five sentences
4. Identify the SPECIFIC QUESTION(S)
5. Identify the approach
6. Draw a diagram for experiments, showing methods
7. Summarize results for each experiment
8. Do results answer the SPECIFIC QUESTION(S)?
9. Read conclusion/discussion/interpretation section
10. Now, read the abstract.
11. What do other researchers say about this paper?

- Dr Jennifer Raff



Step-by-step instructions for reading a primary research article

1. Begin by reading the introduction, not the abstract.

The abstract is that dense first paragraph at the very beginning of a paper. In fact, that's often the only part of a paper that many non-scientists read when they're trying to build a scientific argument. (This is a terrible practice—don't do it.). When I'm choosing papers to read, I decide what's relevant to my interests based on a combination of the title and abstract. But when I've got a collection of papers assembled for deep reading, I always read the abstract last. I do this because abstracts contain a succinct summary of the entire paper, and I'm concerned about inadvertently becoming biased by the authors' interpretation of the results.

2. Identify the BIG QUESTION.

Not “What is this paper about”, but “What problem is this entire field trying to solve?”

This helps you focus on why this research is being done. Look closely for evidence of agenda-motivated research.

3. Summarize the background in five sentences or less.

Here are some questions to guide you:

What work has been done before in this field to answer the BIG QUESTION? What are the limitations of that work? What, according to the authors, needs to be done next?

The five sentences part is a little arbitrary, but it forces you to be concise and really think about the context of this research. You need to be able to explain why this research has been done in order to understand it.

4. Identify the SPECIFIC QUESTION(S)

What **exactly** are the authors trying to answer with their research? There may be multiple questions, or just one. Write them down. If it’s the kind of research that tests one or more null hypotheses, identify it/them.

Not sure what a null hypothesis is? Go read [this](#), then go back to my last post and read one of the papers that I linked to (like [this one](#)) and try to identify the null hypotheses in it. Keep in mind that not every paper will test a null hypothesis.

5. Identify the approach

What are the authors going to do to answer the SPECIFIC QUESTION(S)?

6. Now read the methods section. Draw a diagram for each experiment, showing exactly what the authors did.

I mean *literally* draw it. Include as much detail as you need to fully understand the work. As an example, here is what I drew to sort out the methods for a paper I read today ([Battaglia et al. 2013: “The first peopling of South America: New evidence from Y-chromosome haplogroup Q”](#)). This is much less detail than you’d probably need, because it’s a paper in my specialty and I use these methods all the time. But if you were reading this, and didn’t happen to know what “process data with reduced-median method using Network” means, you’d need to look that up.

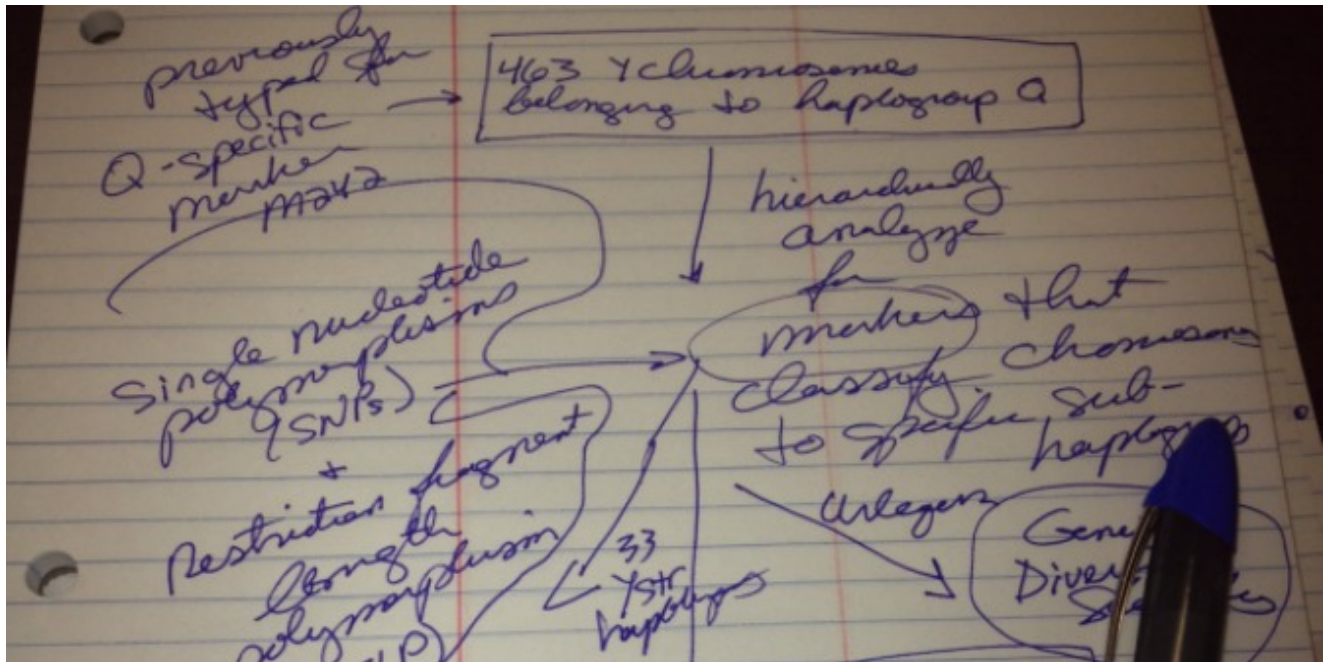


Image credit: author

You don't need to understand the methods in enough detail to replicate the experiment—that's something reviewers have to do—but you're not ready to move on to the results until you can explain the basics of the methods to someone else.

7. Read the results section. Write one or more paragraphs to summarize the results for each experiment, each figure, and each table. Don't yet try to decide what the results mean, just write down what they are.

You'll find that, particularly in good papers, the majority of the results are summarized in the figures and tables. Pay careful attention to them! You may also need to go to the Supplementary Online Information file to find some of the results.

It is at this point where difficulties can arise if statistical tests are employed in the paper and you don't have enough of a background to understand them. I can't teach you stats in this post, but [here](#), [here](#), and [here](#) are some basic resources to help you. I STRONGLY advise you to become familiar with them.

Things to pay attention to in the results section:

- Any time the words “significant” or “non-significant” are used. These have precise statistical meanings. Read more about this [here](#).
- If there are graphs, do they have error bars on them? For certain types of studies, a lack of confidence intervals is a major red flag.
- The sample size. Has the study been conducted on 10, or 10,000 people? (For some research purposes, a sample size of 10 is sufficient, but for most studies larger is better).

8. Do the results answer the SPECIFIC QUESTION(S)? What do you think they mean?

Don't move on until you have thought about this. It's okay to change your mind in light of the authors' interpretation—in fact you probably will if you're still a beginner at this kind of analysis—but it's a really good habit to start forming your own interpretations before you read those of others.

9. Read the conclusion/discussion/Interpretation section.

What do the authors think the results mean? Do you agree with them? Can you come up with any alternative way of interpreting them? Do the authors identify any weaknesses in their own study? Do you see any that the authors missed? (Don't assume they're infallible!) What do they propose to do as a next step? Do you agree with that?

10. Now, go back to the beginning and read the abstract.

Does it match what the authors said in the paper? Does it fit with your interpretation of the paper?

11. FINAL STEP: (Don't neglect doing this) What do other researchers say about this paper?

Who are the (acknowledged or self-proclaimed) experts in this particular field? Do they have criticisms of the study that you haven't thought of, or do they generally support it?

Here's a place where I do recommend you use google! But do it last, so you are better prepared to think critically about what other people say.

(12. This step may be optional for you, depending on why you're reading a particular paper. But for me, it's critical! I go through the "Literature cited" section to see what other papers the authors cited. This allows me to better identify the important papers in a particular field, see if the authors cited my own papers (KIDDING!....mostly), and find sources of useful ideas or techniques.)

UPDATE: If you would like to see an example of how to read a science paper using this framework, you can find one [here](#).

I gratefully acknowledge Professors José Bonner and Bill Saxton for teaching me how to critically read and analyze scientific papers using this method. I'm honored to have the chance to pass along what they taught me.

I've written a shorter version of this guide for teachers to hand out to their classes. If you'd like a PDF, shoot me an email: [jenniferraff \(at\) utexas \(dot\) edu](mailto:jenniferraff@utexas.edu). For further comments and additional questions on this guide, please see the Comments Section on [the original post](#).

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Jennifer Raff (Indiana University—dual Ph.D. in genetics and bioanthropology) is an assistant professor in the Department of Anthropology, University of Kansas, director and Principal Investigator of the KU Laboratory of Human Population Genomics, and assistant director of KU's Laboratory of Biological Anthropology. She is also a research affiliate with the University of Texas anthropological genetics laboratory. She is keenly interested in public outreach and scientific literacy, writing about topics in science and pseudoscience for her blog (violentmetaphors.com), the [Huffington Post](#), and for the [Social Evolution Forum](#).
