

How to Read a Scientific Paper: A Step-by-Step Guide

Scientific papers are extremely difficult to read. They are written by researchers, not writers, and for other researchers to understand. However, by approaching these papers differently from other materials, you can still figure out what these papers are attempting to communicate and learn from them. Before you begin, keep in mind two things. First, **do** take notes as you read. This guide will also point out specific things to note down, but taking notes on parts and words you don't understand will let you come back to these later, and taking notes on important terms and explanations will let you return to these when they are referenced later on. You can either write these notes on a separate paper or take notes on a copy of the paper and annotate it, whichever works best for you.

Second, keep your purpose in mind as you read. If you are summarizing the paper, you will want to pay extra attention to the title and abstract. If you are using the paper as a source for your own research paper, you will want to pay a lot of attention to the introduction and discussion/conclusion. If you are reading the paper to learn more about a topic, you will want to spend more time on the methods and results sections. It is very important to keep in mind what sections matter most to **you** as you read.

Step-by-Step Instructions:

Step 1: Skim the abstract.

The abstract serves as a brief summary of the paper, and while they tend to be very hard to understand, it can help you understand what the **author** thinks is most important about the paper.

Step 2: Start to read the introduction.

This section will start out with the background for the topic and will often be the easiest to understand part of the paper, so read all of it and take notes on the reason the research is being conducted. This section will also likely be filled with in-text citations, and individual sentences may not make a lot of

sense since they are attempting to sum up the results of other papers, so don't worry too much if you have trouble with some sentences, just move on.

Step 3: Continue reading the introduction and search for the motivations and goals of the researcher(s).

After the background is discussed, this will be the rest of the introduction and will frame the rest of the paper. Write down the following in your notes as you go: What questions do the author(s) propose? What seems to be the big problem that this research plays into? Is this research attempting to directly find the solution to that problem or is it trying to learn about what that problem will do (for example, is it trying to prevent a species from going extinct, or is it trying to determine how that extinction would affect another species)? Additionally, try to find a hypothesis if possible, though this may be difficult to identify since researchers do not often use the word "hypothesis" in their papers.

Step 4: Decide whether to read the methods section or not.

This section discusses how the research was conducted, but most of the time that information is not what you are looking for. If you do need this information, skim the section and write down key points in the research process. Then, assemble this into big steps in the research process. If you look at each of these steps on their own, understanding the broad strokes of how research was conducted becomes much easier. Literally drawing this as a diagram may also help you.

Step 5: Skim the results section for graphics and visuals.

The results section tends to be the most dense and difficult part of the paper to read. It is focused on the raw data that the research produced and is meant mostly for other researchers to check the author's work. Focus only on visuals (like charts and graphs) and their captions, and take notes on what each graph shows, since these tend to be much easier to understand and are usually meant to summarize data.

Step 6: Read the conclusion/discussion/interpretation.

Usually these are all used to describe the same section. This section summarizes what the author thinks their results mean and how that factors into the bigger picture. Read this full section and write down the main conclusions that the author comes to and write a summary of why this is important. Also write down if the author(s) say anything about where “further research” is needed. If there is a separate conclusion and discussion/interpretation section, treat them as if they are the same section.

Step 7: Compare the initial questions and goals to the discussion.

This is one of the most important steps. Ask yourself: “Does the author find answers to the questions they asked at the start?” The answer to this might be no. Compare the notes you took during the introduction to the notes you took in the last step and write down what parts of the introduction were answered and which were not.

Step 8: Decide where to go next.

This part will likely vary a lot depending on your goal as the reader, but consider these questions: Where does this research go next? How does this affect the larger picture? Was there something that you didn’t understand and want to learn more about? All of these are great questions that will help you decide where to go next.

Appendix 1: Anatomy of a Scientific Paper

Title

This can be easy to forget about, but the title holds meaning as well. While the abstract summarizes the paper as a whole, the title summarizes just the goal of the paper.

Abstract

A brief summary of a paper. This is usually very dense, but it's worth reading because it gives you a good idea for what the paper will be discussing and what you should be keeping an eye out for.

Introduction

A section with two main purposes. First, to give background information to catch anyone outside of the field up to speed. This will include information on the big issues the paper is trying to address. Second, to introduce what the paper is specifically addressing and trying to solve. This is an extremely valuable section and tends to be much more accessible than the rest of the paper.

Methods

This is how the researchers conducted their research. If you are summarizing the paper, it is important to read this, but otherwise you can often fully skip this part. The information is valuable, but if you are only interested in the conclusions, this section won't give you any information.

Results

This is where the raw results are reported. This section will likely be the hardest to understand, but visuals and graphs in the section can give you a good feel for the overall results.

Discussion/Conclusion/Interpretation

This section can go by any of these names but is generally very similar. This is where the authors state what they think their results mean and why that's important. If you had trouble understanding the results section, pay more attention to this section.

Appendix 2: Key Terms

Many terms used in science do not mean what they normally mean. This appendix contains explanations about some words that may be confusing.

Significant/Non-Significant: In science, it is impossible to fully confirm that something is 100% true. Instead, researchers look for “significance,” which means that something is incredibly likely to be true. If a value is “non-significant,” it is not necessarily false, but it can not be confirmed to be true.

P value: A p value (or p test) is a common method of measuring significance.

“Blind” Studies: Studies where participants are unaware of whether they are in the control or experimental group to reduce bias. Double-blind studies mean that the researchers also don’t know who is in which group.

Error and Bias: Both are terms used to describe how much difference there is between predicted and observed results. However, bias is caused by an issue with the experiment’s methods, while error is a natural result of things not being perfect.

Positive/Negative: These terms do not mean something is good or bad. Instead, they mean that something was added or a value increased (positive) or something was removed or a value decreased (negative).

Confidence Interval: Confidence is used similarly to significance. A confidence interval is the range that results should land in to confirm that a hypothesis is probably true.

Correlation vs. Causation: Correlation means that two trends are similar, so they might be influencing each other. Causation means that the trends have been confirmed to influence each other. Causation is much harder to prove than correlation.

Appendix 3: How to be Critical

Critiquing a scientific paper can feel very daunting, but it is perfectly valid to do so. Papers are never perfect, and in some cases may actually be meant to cause harm. We can critique in two main ways: critiquing a paper's source and critiquing the paper itself. We'll start with the former, then after we have established the paper as a valid source, we can start to investigate the paper itself.

Step 1: What journal was it published in?

The journal that an article is published in is very important. Most papers are not published in universally known journals, such as *Science* or *Nature*, and just because a journal has a legitimate sounding name does not mean that it is reliable. Not all journals are peer reviewed, some are heavily sponsored by certain industries, politicians, or activist groups and will be heavily biased, and some are even journals that used to be well renowned but have been "hijacked", with their website or other information being stolen and used to publish bad papers. While a paper being from a legitimate journal does not mean it is a good paper, you can quickly eliminate bad papers by verifying if their source is legitimate and peer reviewed. Additionally, if you can not identify what journal a paper is from, it is possible it is not a published paper at all, and you should avoid it.

Step 2: Who is/are the author(s)?

There are a few reasons that the authors of a paper might be a reason for concern in a paper. First, check if the author is an expert in the field they are researching. Just looking up their name can often find their affiliated university or group and some information about them. You can also do an author search on a service like *Google Scholar* to find what other papers they have studied to see if the paper you're reading seems to be in their specialty. Second, look to see if the author has a history of retractions or errata. It is okay for authors to have a few retracted or errata papers, but having several might be a warning sign that the author has a history of error-filled or even fraudulent papers. A great tool for finding this is *Retraction Watch's* database, which compiles retractions and errata from papers all over the globe.

Step 3: What other sources do the author(s) cite?

At the end of any research paper there will be a long list of citations. Having dozens of citations is not just common, it's the standard. Some of these may be difficult to locate, but you can likely find many of them just looking them up. You don't need to do a full analysis of them, but taking a quick look at some of the sources can give you a feel for if they are also trustworthy sources. If a paper cites untrustworthy sources, it is likely not trustworthy itself!

Step 4: Do the Initial Questions, Results, and Discussion all match?

This might seem obvious, but it's something that even some legitimate papers lose track of. Check your notes for the background, results, and discussion sections, and particularly compare the key questions with the key conclusions. Do they match up? Were the key questions answered, and if they were, do the results back them up? If these sections do not match, even if the research is valid, the conclusions it reaches may not be reliable.

Step 5: Analyze the Methods

When doing a critical analysis of a paper, the methods section is extremely important, and this is a large part of why the section exists: so other people can check the researcher(s) work. This may seem like a very difficult task, and it isn't easy, but focus on answering these questions: Do these methods seem like a good way to answer the key questions? Are the methods prone to bias or error? Are there other factors that you can think of that might affect the results but that the researchers don't mention?