Reading a Scientific Article

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Welcome to the Office of Intramural Training & Education Webinar on Reading a Scientific Article. This is intended to be a first step in understanding the basics of scientific articles and in helping you get started reading and analyzing scientific papers. We will be using scientific article and scientific paper interchangeably throughout the presentation.

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In this Webinar, we will go over the fundamentals of scientific papers, including the different types of scientific literature available and the structural elements of a scientific article. Also, we will cover the importance of scientific papers, why do we read them, and how do we decide which papers to read. Finally, we will discuss some of the guidelines for reading a scientific paper and critically reviewing it.

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Scientists communicate with each other through the scientific literature, which becomes a repository of current and past scientific knowledge. Scientific literature can be separated into different categories: primary, secondary, tertiary, and gray literature.

Primary literature reports original findings that can be directly attributed to the authors. The authors are the scientists who do the research and write the paper. Primary literature includes different types of papers, such as original articles, case reports, and technical notes. Original articles report novel scientific findings that are usually supported by extensive evidence and statistical analysis, making them the most important type of paper in the scientific field. Case studies describe cases with unique characteristics, like an unusual clinical condition or a previously unreported side effect of a treatment. Finally, technical notes describe novel techniques in detail.

Publications that use primary literature as the main source of information are called secondary literature. The objective of such papers is to provide an overview of a specific scientific topic. For example, review articles summarize recent developments in a specific research field, and highlight the major findings reported in the literature. Books, textbooks, and manuals are other examples of secondar literature.

Tertiary literature targets an informed lay audience or scientists that are not experts in the field. It includes science articles in newspapers or in popular science magazines.

Finally, gray literature refers to written materials that are not published or might be more difficult to access. Examples include dissertations, theses, or conference proceedings that are only made available to attendees.

In this Webinar, we will specifically be focusing in reading original articles in the primary literature.

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Most original articles follow a conventional structure: a title and an abstract, followed by sections fo introduction, methods, results and discussion, and finall short acknowledgements and references. Figures and tables generally display the actual data described in the article.

We can describe the structure of scientific papers with the acronym IMRaD, which stands for the central sections of an original article: the Introduction, Methods, Results, and Discussion. Even though most journals follow this conventional structure, there are exceptions to the rule. For example, some journals combine the results and discussion sections or include a summary at the end. Additionally, the widely read journals *Science* and *Nature* depart drastically from the conventional structure. They do not allow any discrete sections except for abstract, references, and, sometimes, a short methods section.

There is also variation between journals in the length and style of the papers. Each journal has its own specific requirements for publication such as word count limits and section specifications. For example, the journal *Cell* has a word count limitation of around 7,000 words for their research articles, while papers for the journal *Science* are more concise as the journal only allows 4,500 words.

Currently, most papers also include supplemental materials that can be accessed online. These could be additional data, results, or more detailed methodolog explanations.

Each element of a paper is defined by specific characteristics. Being aware of these features will help you read and comprehend a paper.

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The title of the paper should describe and highlight the main findings of the research. It is a great starting point to identify the take-home message of the pape and whether the paper will be of interest to you.

For example, this is a title of a recent article in the journal *Science:*

“Neurotransmitter Switching in the Adult Brain Regulates Behavior“

This title highlights the main findings of the paper. The authors found that modifying the day/night patterns of adult rats causes neurons to switch their neurotransmitters, which are the chemicals that transmit signals from a neuron to a target cell. These changes in neurotransmitters also regulated the rats’ behavior, which was the key research finding.

Research papers list contributing authors after the title. In the neurotransmitter example, four authors are listed. For papers in biomedical research, the order of the authors is important. The first author is the person who has done most of the research. Then, the authors follow in decreasing order of contribution to the paper. Finally, the last author is usually the head of the laboratory or the principal investigator. So, if you were interested in a specific topic, such as the regulation of behavior, you can search for papers published by the last author, in this case, Dr. Nicholas Spitzer. Papers also identify one or two corresponding authors, who are the authors you should contact if you have specific questions.

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After the title and the authors, comes an abstract, which is a short summary of the work. Abstracts usually contain four types of information which parallel the structure of a paper. First comes the introduction, where authors establish the purpose or rationale for the study, namely, why did the authors decide to pursue this line of research. Second, the methods, which include how the authors did the research or the methodology they used. Also, abstracts point out the main finding of the paper which would be the results and, finally, a brief interpretation of the results and what they mean for the scientific community, which parallels the discussion.

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Here is the abstract of the paper I previously mentioned on neurotransmitters and behavior in rats. As you will see, it is a mini-paper and includes information from all the conventional research paper sections.

First, the introduction: “Neurotransmitters have been thought to be fixed throughout life, but whether sensory stimuli alter behaviorally relevant transmitter expression in the mature brain is unknown.“ Here, the authors establish the purpos and rationale of the study.

Then the abstract includes information on the methods and results: “We found that populations of interneurons in the adult rat hypothalamus switched between dopamine and somatostatin expression in response to exposure to short- and long-day photoperiods.” The abstract contains a few more sentences detailing more specific results on the paper.

Finally, the abstract includes a brief interpretation of the results or their significance for the scientific field: “Natural stimulation of other sensory modalities may cause changes in transmitter expression that regulate different behaviors.”

As you can see with this example, the abstract follows the structure of a paper including an introduction, methods, results, and discussion.

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Introductions put the research of the paper into context. They serve two purposes. First, introductions create interest in the subject area by explaining the current state

of a specific scientific field and mentioning why the work is important. Also, introductions provide enough background information to allow the reader to understand the article. They do this by following a common structure. Usually, they will start by giving a broad overview of what is already known in the field and, then, focus on the specific finding or set of findings that was critical for the research described in the paper. Finally, introductions state the questions the research seeks to answer, the specific predictions or hypothesis being tested and, sometimes, the main conclusions reached.

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The materials and methods section usually follows the introduction, although some journals place it at the end of the paper. This section describes exactly what the researcher did, lists the materials used in the experiments, and explains the methodology and statistical methods used to carry out the experiments and analyz the data.

This section can be one of the hardest ones to read, due to its very technical language and the level of detail provided. Ideally, the materials and methods should be detailed enough to allow any scientist to replicate the results. However, in practice, this section is usually highly compressed and frequently contains references to previous papers.

To understand the design of the experiments and to critically evaluate a paper, it is necessary to read the materials and methods section carefully.

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The results section outlines the experiments and the data analyzed in the article. It is a logical extension to the questions set up in the introduction. It usually follows the data in the order it is presented in the figures and tables. Commonly, the data described in the first figure can support different explanations, which are then addressed in the following experiments, thus moving from general to specific Results often also include multiple experimental approaches that are used as a group to support a particular conclusion.

In the results section, authors should not compare their findings to previous work nor provide interpretation of the data presented; these belong in the discussion section. Occasionally, authors have to include some interpretation of the data, so the reader can understand the rationale of the following experiments. However, most of the time these explanations are instead located in the discussion section.

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In the discussion, authors interpret the results obtained and logically explain how the data support their conclusions. They also should mention any limitations of their experiments or any alternative explanations that, although probably less likely, could also be supported by the data.

The discussion also places the findings in the context of the broader scientific field. Authors might connect their work to previous reports and, thus, make a stronge case for their conclusions.

Finally, discussions usually include some mention of the future directions of the research.

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Papers usually end with an acknowledgments section and always have a references section.

The authors of the paper should have significantly contributed to performing the experiments, writing the manuscript, and/or designing or modifying the experiments. Contributions of scientists, other than the authors, are recognized in the acknowledgements. These contributions can include sharing specific materials or providing comments to improve the manuscript.

The references section cites all of the papers mentioned in the article. Authors should never include statements of fact or present ideas that are not their own without giving credit to the original authors. Doing so would be considered plagiarism, which is a serious offence in the scientific community. The references section is very useful for finding similar research papers or more information on a specific subtopic. Also, it gives you an idea of what type of research other groups are doing.

Now let's move on to discuss strategies to read a scientific paper.

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It is important to understand the many reasons why scientists read research papers. Why you read a paper will direct how you read it.

First, you could read a scientific paper to acquire general background knowledge on a specific topic. In this case, you would only have to understand the main points of the paper and would not have to read it in much depth. You might also focus you efforts on the introduction and the discussion.

Second, you could read a scientific paper to gain specific knowledge of your own field. Scientific papers are the most current and reliable source of information for scientists, so they allow you to follow scientific breakthroughs in your field. Science is all interrelated and current research findings will guide your own project. Reading a paper for this purpose will require you to spend more time in understanding the methodology, the main points, and the implications of the research.

Also, scientific papers generally give you enough information to replicate an experiment. You can refer to the methods section and the references to apply a specific technique in your research project. You could even use the same experiment

reported in the paper as a positive control or as proof of principle that the techniqu is actually working in your hands.

Finally, reading scientific articles can be a great tool in preparing you to write you own papers. The more articles you read, the better understanding you will have of their structure and style, which will eventually guide your own writing.

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Thousands of scientific articles get published each week, so it is important to decide carefully what papers you would like to read.

Consider setting a clear objective for reading a particular paper and identifying what you would like to get out of it. Your objective will determine the approach you will take in reading a specific paper. For example, if your objective is to get an overview of a topic, you can probably skim the paper. However, if you need to explain the findings to others, or if you encounter an article that is essential for your future research, you will want to analyze the paper closely and critically evaluate it. This approach will be much more in depth, more labor intensive, and time consuming.

When you approach a paper, first read the title and the abstract and identify what the authors found. Depending on your goal, decide if the paper is useful to you now. If this is the case, then read it. If the paper is not useful to you immediately but might be useful in the future, save it or file it, and read it later when you have more time or when it becomes more pertinent to your research. Also consider askin yourself if the paper is useful to you at different times during your reading process If, at some point, you realize that the paper does not meet your objective, you can reconsider if you want to finish reading it, or if you should save it for later or skip it altogether.

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Once you have a clear idea of what your goal for reading a particular paper is, move through the article from the general to the more specific.

First, start broad to develop a framework to understand the paper. It is important to get a general understanding of the main points and identify how much you already know about the topic. After gaining a general overview of an article, you can move on to gain a deeper understanding of the findings and critically evaluate the work presented.

When reading a paper, you don't need to follow a linear approach. A scientific article should not be read in the same way as you read a textbook. It is better to read specific sections before others and sometimes go back and forth between sections.

Finally, reading a scientific paper is an active process. In order to get a deeper understanding of the paper, you should take notes and ask questions while you are reading.

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Focus first on the title and abstract. Both the title and the abstract are descriptive of the work and, hopefully, contain the most important information in a ver condensed form. Take your time to mentally process the information from these two elements. Also, review in your mind what you know about the topic. First, this will help you identify if you have enough background to appreciate the paper or whether you should review additional sources. Also, this mental exercise helps you refresh your memory about the topic and integrate new information with prior knowledge.

You should then skim the article and analyze the document as a whole. Take a look at key features of the paper such as the section headings, the figures and tables, and important paragraphs such as the first and last paragraphs of the introduction and discussion. Analyzing the structure of the article will help you identify which sections contain essential material and decide the order in which you will read the sections.

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Once you acquire a general understanding of the whole paper, you can then proceed to analyze the paper in more depth. Even though scientific papers should not be read linearly, there is no one correct way of reading a scientific article. Th order you end up following will depend on your own preference, the specific paper yo are reading, and your knowledge of the particular field. Two common strategie include reading the introduction first, followed by the results, and finally the discussion, or starting with the discussion, continuing with the introduction, and, finally, looking at the results. If you are very familiar with the topic, you could also start with the figures, then move to the discussion, and finally the methods. Usually the methods section can be read last or you can refer to it as needed. It is ver important to also continuously refer to the figures and tables as you are reading the paper, especially when analyzing the results and discussion sections. Verify that the statements in the text match the data shown. The information in the paper is organized around the data shown in the figures and tables. It is important not to forget about their central role.

Because articles contain so much information, you may find it difficult to distinguish the main points. Fortunately, there are many key words or phrases that are traditionally used and can act as helpful indicators. Some examples include adverbs such as “surprisingly” or “unexpectedly”, and also phrases like “in contrast with previous work”, this problem “has seldom been addressed”, also “we hypothesize”, “we propose”, or “we introduce”, and “the data suggest”. These are only a few examples of commonly used phrases that signal critical points in a paper. The more papers you read, the easier it will be to identify these helpful phrases.

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At all times try to be aware of your own understanding. Make sure you question your understanding before, during, and after reading a scientific paper. Ask yourself

questions such as “who are these authors?”, “what journal is this?”, “what is the main question or questions addressed?”, “what were the data or results that emerged from the study?”, “what did the authors conclude?”, “what is the significance or importance of this study?”, “how does this article relate to others I have read?”, and “what questions are still unanswered?” These are just a few examples of questions you should be asking yourself throughout the process of reading a scientific paper. Playing an active role while you read will help you be better prepared to critically evaluate the paper.

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To critically evaluate a paper, you should examine different elements.

First, determine the main question being addressed. A paper can focus on different types of questions. For example, descriptive questions rely on observations of a system and often arise in our early understanding of a process, before actual hypotheses can be formulated. In contrast, comparative questions aim to identif how general a finding is, and if it specific to a particular system or organism or if it can be applied more broadly. Finally, analytical questions can be formulated when there is enough information to frame a specific hypothesis and explore the mechanism of action of a particular process or system. Of course, these approaches are not mutually exclusive. Indeed, many papers ask a combination of these types of questions. Having a clear understanding of the particular questions asked in a paper is essential in analyzing the value of the evidence and the significance of the findings.

When examining the evidence and the statistics, pay particular attention to the methods section. It is important to understand the experimental design, the inclusion of controls, and whether there are any modifications from standard protocol. Also, it is critical to verify if results are statistically significant and if statistical tests are applied properly. This information will allow you to gauge the validity of the evidence.

Then, examine the conclusions of the paper. To identify the conclusions, you can refer initially to the abstract and then to the discussion. You can decide whether the data actually support the conclusions or interpretations of the authors. First, determine if there is a logical connection between the data and the conclusion. Many papers develop several lines of evidence supporting a particular conclusion, allowing the authors to make a more persuasive argument. To understand the validity of the conclusions, it is important to examine whether the assumptions made by the authors are reasonable. This can be hard to do unless you understand the field thoroughly. Also, consider whether there are alternative interpretations Authors will sometimes include these in the discussion, but this is not always the case.

Finally, when critically evaluating a paper, it is important not only to identify the limitations but also to acknowledge the merits of the paper.

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Again, it is extremely important to take an active role when reading a scientific paper. This will not only help you better understand and remember the material but will allow you to identify areas of difficulty.

Ideally, you should find a quiet place free of distractions. Reading a paper requires concentration. Try to take notes as you read and highlight the major points. This will help you organize and process the information as you go through the paper. Also, react to the points in the article. If you find something that relates to other work, a weak statement, or a pleasing quote, make a note of it. Finally, summarize what yo read. Try to write a summary with your own words and include the main point such as the significance, the main findings, and the conclusions.

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To summarize, we discussed that there are many different types of scientific literature, including primary, secondary, tertiary, and gray literature.

Original articles follow a defined structure, which includes the title, abstract, introduction, methods, results, and discussion. They also have references and generally, an acknowledgement section. Each of these elements consists of standard features.

When reading a paper, first try to get a general overview to form a framework. This can be accomplished by reading the title and abstract carefully, and then browsin through the rest of the paper. Afterwards, read carefully and critically evaluate the results and conclusions. Finally, remember to take an active role while reading, and try to take notes, highlight main points, and summarize the work with your own words.

Keep in mind why you are reading a specific paper. Your objective will guide your reading approach. If at any point, you realize that the paper is not meeting that purpose, reconsider your reading strategy and whether you should be reading it at all.

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The content of this Webinar was adapted from several sources available at different institutions. If you would like to find additional information, please refer to the links indicated in the slide. Thank you.