

## The Discussion Section: Your Closing Argument

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In the judicial system in many countries, a jury decides the final outcome in a court case. The proceedings begin with a lawyer providing an opening statement telling the jury what he or she plans to present. Through a variety of chosen tactics and methods, the lawyer then presents the various pieces of evidence, all of which lead up to the closing argument. A poor closing argument can hurt even the best case. A great closing argument can convince the jury that the evidence is sound and the lawyer's interpretation of it has merit. In the original *Law & Order* TV show, which incorporated both the investigation of a crime and the courtroom proceedings, the closing arguments were often the most compelling and defining moments in the show.

The Discussion section in a scientific paper and the closing argument in a courtroom have similarities. For many readers, the most important information is not what your results show but what your results mean. The purpose of the Discussion section is to explain what your results mean and what contribution your paper makes to the field of study. The Discussion section is your closing argument. Numerous scientists have told me that when reading a paper they first look at the Abstract to get an overview of the topic and the purported findings. If the topic appears to be of interest, they then skip to the Discussion section. If the Discussion is neither stimulating nor convincing about the meaning and importance of the findings, it does not really matter how the experiments were performed or what results were reported. A poor Discussion detracts from a scientific paper. A good Discussion adds a strong finish to a scientific paper. It brings meaning to your study. My goal with this article is to help you understand the characteristics of a good Discussion section.

### Invert the Cone

In a previous article on the Introduction section of a scientific paper (1), I discussed how this section could

be envisioned as having the shape of a cone or funnel. The information in the Introduction flows from broad to narrow. The first paragraph provides general background material on the topic, and the last paragraph focuses on the specific question(s) being asked in the study.

In contrast, the Discussion can be envisioned as an inverted cone or funnel, from which the flow of information goes from narrow (top) to broad (bottom). This analogy helps to emphasize the need for the first paragraph of the Discussion to be very specific and focused. This goal is accomplished by getting right to the point, which is to answer the question(s) presented in the Introduction. As Zeiger states (2), "Thus, the answer to the question is the culmination of the paper. It deserves the most prominent position in the Discussion—the beginning." The hypothetical example below shows how the Discussion picks up where the Introduction leaves off.

#### End of the Introduction:

*We therefore investigated whether  $\beta$ -selectin, vascular lipoprotein-binding molecule (VLM), and interleukin-6 $\gamma$  (IL-6 $\gamma$ ) play a role in the vascular inflammation associated with atherosclerotic disease or are just markers that reflect vascular inflammation. Using a herpes simplex virus type 2 (HSV2) infection protocol to stimulate continuous production in mice, we investigated the effects of  $\beta$ -selectin, VLM, and IL-6 $\gamma$  production on the development of atherosclerotic lesions.*

#### Beginning of the Discussion:

*In this study, we investigated whether  $\beta$ -selectin, VLM, and IL-6 $\gamma$  play a role in the vascular inflammation associated with atherosclerotic disease or are just markers that reflect vascular inflammation. Our results show that in mice, IL-6 $\gamma$  (a) appears to play a role in vascular inflammation and (b) increases the development of atherosclerotic lesions.*

Three points about the beginning of the Discussion are worth emphasizing here. First, because the Introduction and Discussion sections are separated by other sections of the paper, it is acceptable to provide in the Discussion an introductory sentence that restates the question or purpose of the study. One sentence is usually enough. Second, the restatement at the beginning of the Discussion must match the statement of purpose in the Introduction. In the example above, the authors found it convenient to use the same sentence

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from the Introduction to restate their purpose in the Discussion (boldface text). Third, it is important to answer the question as it was asked in the Introduction, with the same words and key terms. In the example, the authors indirectly asked 2 questions in the Introduction: whether any of 3 compounds played a role in vascular inflammation and whether these compounds had any effects on the development of atherosclerotic lesions. The second sentence of their Discussion thus contains 2 answers (boldface text) that clearly match the original questions in both wording and key terms.

After answering a specific question with a specific answer, you need to describe how the answer is supported by your results:

*Our first finding that IL-6 $\gamma$  appears to play a role in vascular inflammation is supported by our protein expression experiments. Twenty-four weeks after injection with cDNA-transfected viral units, only  $\beta$ -selectin was present in sera from mice injected with HSV2- $\beta$ -selectin, and only VLM was in sera from mice injected with HSV2-VLM. The injection of mice with HSV2-IL-6 $\gamma$ , however, yielded not only high serum IL-6 $\gamma$  concentrations as expected but also high concentrations of VLM and  $\beta$ -selectin, both of which are known to increase with vascular inflammation. Our second finding that IL-6 $\gamma$  appears to contribute to the formation of atherosclerotic lesions is supported by our observation that the mean areas of lesions in mice injected with HSV2-IL-6 $\gamma$  were nearly 3-fold larger than the mean areas of lesions in control mice.*

The scope of the Discussion should then be broadened by describing how your results and your interpretation of the results are supported by, consistent with, or related to the results (evidence) from other published studies. If your results support the work of others, you can also use this approach to discuss your results:

*Evidence of a possible linkage between serum IL-6 $\gamma$  concentrations and the formation of atherosclerotic lesions comes from the study by Proctor and Schlessler. These authors showed that dietary polyphenols in fruits and vegetables decrease the size and number of atherosclerotic lesions. A secondary finding in their study, which was not explored further, was the observation that polyphenols also reduce serum IL-6 $\gamma$  concentrations. Additional evidence comes from recent studies showing that HMG-CoA reductase inhibitors rapidly reduce both serum C-reactive protein and IL-6 $\gamma$  concentrations, followed by a reduction in arterial plaque density.*

Or:

*Previous studies have found an association between serum IL-6 $\gamma$  concentrations and the formation of atherosclerotic lesions. Proctor and Schlessler showed that dietary polyphenols in fruits and vegetables decrease the size and number of atherosclerotic lesions. A secondary find-*

*ing in their study, which was not explored further, was the observation that polyphenols also reduce serum IL-6 $\gamma$  concentrations. A second study by the Canadian All Cause Mortality Coalition showed that HMG-CoA reductase inhibitors rapidly reduce both serum C-reactive protein and IL-6 $\gamma$  concentrations, followed by a reduction in arterial plaque density. The results of our study not only confirm an association between IL-6 $\gamma$  and the formation of atherosclerotic lesions but also show that overproduction of IL-6 $\gamma$  promotes the formation of atherosclerotic lesions.*

Toward the end of the Discussion, the “big picture” should now be considered. It is important to describe the contribution your study makes to the field and how your findings can be applied to existing and future studies. For example:

*Our demonstration that increased production of IL-6 $\gamma$  is associated with both vascular inflammation and a significant increase in the size of atherosclerotic lesions indicates the existence of multiple pathways that can promote vascular inflammation. It should be possible to design IL-6 $\gamma$  antagonists as therapeutic agents for those individuals who have high serum IL-6 $\gamma$  concentrations. Structural analog antagonists have already been described for IL-4, which plays a role in the allergic response. Another similar advance that supports the potential benefit of IL-6 $\gamma$  reduction is the development of tumor necrosis factor  $\alpha$  antagonists that have been effective in treating rheumatoid arthritis.*

Close the Discussion with 1 or 2 sentences that provide a take-home message for the reader. This take-home message can restate the answer one last time and/or indicate the importance of the work by stating implications, applications, or recommendations (2). It is important, however, not to repeat items already discussed. Some journals include an actual Summary or Conclusion section at the end of published articles, where these summary points belong. Whether such a message is considered a summary or a conclusion, the worst thing you can do is end with a weak statement, such as “further work is needed to solve this problem,” or “we plan on conducting future experiments,” or “we have already begun experiments to test our new theory.” The final sentences should provide a strong finish:

*In summary, our study shows that IL-6 $\gamma$  induces the production of known inflammatory markers and appears to cause an increase in the size of atherosclerotic lesions in mice. Since IL-6 $\gamma$  binds to a different receptor family than C-reactive protein in both mice and humans, there are now at least 2 mechanisms that must be considered when developing new strategies to reduce the incidence and severity of atherosclerotic disease.*

## Be Fair and Balanced

There is a major news network in the US that has used the trademark slogan “fair and balanced”—fair by being impartial and free from bias, and balanced by presenting all sides of a story. Your Discussion section should also be fair and balanced. There are important points that should be considered to help achieve fairness and balance (2–4).

First, be sure to give credit where it is deserved. If the methods or results from other studies added an important element to your study design or if the work of others supports your findings, state that in the Discussion. Conversely, if you believe that your work supports the findings of others or improves upon what others have done, give yourself the same credit. The key here is to be factual and not boastful about what you have done:

*Of the 4 published procedures for nucleic acid insertion, we chose the one described by Wallenburg and Hughes because their procedure yields the highest percentage of cDNA-transfected viruses. Other researchers have successfully used the same procedure to generate viral vectors for the in vivo production of ferritin and transcobalamin, 2 smaller proteins with molecular weights in the same range as our 3 proteins. We were able to improve the yield of transfected viruses 2-fold by adding 0.01% glycerol to the trypsin-EDTA solution.*

Second, if you encounter any unexpected results or find that your results (or answer) disagree with other studies, be transparent about these differences, and try to explain them rather than pretending they do not exist:

*Smith et al. previously reported that in vitro exposure of cultured smooth muscle cells to IL-6 $\gamma$  does not elicit the release of  $\beta$ -selectin. We were able, however, to elicit the production of  $\beta$ -selectin when mice were injected with HSV2–IL-6 $\gamma$ . It is known that the vascular endothelium must sense both a hemodynamic pressure change and a modulation in signal from receptor–protein binding before microvascular changes occur. This combination can occur only in vivo. Therefore, the difference between our findings and theirs might be due to the in vivo nature of our experiments.*

Third, use the Discussion section to acknowledge any limitations of your study and any alternative explanations for your findings. Acknowledging limitations up front makes you look better because you considered, even in retrospect, how the study could have been done better or differently. Recognizing alternative explanations shows that you have a good breadth of knowledge of the field and the factors that might have come into play throughout your experiments. Most importantly, acknowledging any limitations of your study or any alternative explanations preempts a peer

reviewer’s discovery of them and the opportunity to point them out. If you can explain how the conclusions drawn from the results are probably not affected, do so:

*One limitation of our study is that our experiments have thus far been conducted only on mice; however, the results for many studies of atherosclerosis, such as those examining the effects of cholesterol-lowering drug therapy, that were originally performed on mice have subsequently been extended to humans. Such evidence suggests that IL-6 $\gamma$  might have the same effect on the formation of atherosclerotic lesions in humans. Another limitation is that the continuous production of IL-6 $\gamma$  in our cotransfected HSV2 model may not reflect the rate of production or the serum concentrations of IL-6 $\gamma$  that would be required to promote atherosclerotic lesions. Our experiments, however, were designed to examine a cause-and-effect scenario rather than a relative response.*

Although our results show that IL-6 $\gamma$  appears to play a role in vascular inflammation and the development of atherosclerotic lesions, its contribution could be primary or secondary in nature. Our initial evidence, when combined with evidence from other studies, supports a primary effect; however, we did not construct a serum or tissue metabolomic profile to identify compounds that might have been up-regulated by increased IL-6 $\gamma$  concentrations. Thus, we cannot discount the possibility that IL-6 $\gamma$  acts in combination with another compound to promote vascular inflammation or that IL-6 $\gamma$  induces the production of another compound that itself is the active agent in vascular inflammation.

## Use Transition Words and Phrases

In my previous article on the Introduction section of a scientific paper (1), I talked about how the story becomes clearer if transition words and phrases are used. Transition words and phrases allow the author to emphasize important points and to help the reader recognize a switch from one topic to another. They also serve the same purpose in the Discussion section. Examples from the hypothetical Discussion above include:

- *Our results show that . . .*
- *Our first finding that . . .*
- *Our second finding that . . .*
- *Evidence of . . .*
- *Additional evidence comes from . . .*
- *Our demonstration that . . .*
- *Previous studies have found . . .*
- *The results of our study not only . . .*
- *Therefore, . . .*
- *However, . . .*
- *Thus, . . .*

## Learning Exercise

Answer the following questions:

1. What is the purpose of the Discussion?
2. How are the formats of the Discussion and Introduction different?
3. Name 3 types of information that should be included in the Discussion.
4. What is a good way to end the Discussion?

## Final Thoughts

There is a well-known saying, “You don’t get a second chance to make a first impression.” This saying certainly holds true if you consider the importance of the title and abstract of a scientific paper; however, for scientific papers there should also be a saying, “You don’t get a second chance to make a final impression.” The Discussion is your opportunity to make a good final impression. If you apply the information presented in this article, you will be on your way to doing just that.

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## Answers to Learning Exercise

1. The purpose of the Discussion section is to explain what your results mean and what contribution your paper makes to the field of study.
2. The Introduction presents information from broad to narrow (from the larger picture to the specific question). The Discussion presents information from narrow to broad (from the answer to a specific question to the larger picture).
3. The Discussion section should include:
  - The answer to the question
  - How the answer is supported by the results
  - How the results are supported by other studies
  - How the results support other studies
  - How the results differ from those from other studies
  - Any limitations to the study
  - Any alternative explanations for the results
4. Restate the answer one last time, and/or indicate the importance of the work by stating implications, applications, or recommendations.