

## CHAPTER 13

# Discussion

### 13.1 OVERALL

The Discussion is usually the hardest section to define and to write. Many papers are rejected by editors because of a bad Discussion section. Even though the data may be valid and interesting, the interpretation or presentation of it in the Discussion may obscure it. Therefore, good style and clear, logical presentation is especially important here.

### 13.2 CONTENT

#### **DISCUSSION GUIDELINE 1:**

State and interpret your key findings. Provide the answer to the research question.

#### **DISCUSSION GUIDELINE 2:**

Summarize and generalize.

#### **DISCUSSION GUIDELINE 3:**

Keep in mind who your potential readers will be.

The main function of the Discussion is to interpret your key findings and to draw conclusions based on these findings—in other words, answer the question(s) asked in the Introduction. The discussion should also explain

how you arrived at your conclusion, compare and contrast your findings with existing knowledge on the topic, and state theoretical implications or practical applications. It should give the paper significance by summarizing and generalizing results while clearly indicating how your study has advanced knowledge.

In the Discussion, explain what is new in your work and say why your results are important. You should also include explanations for any results that do not support the answers and discuss other results and hypotheses that are relevant to yours. In addition, you may discuss any possible errors or limitations in your methods, give explanations of unexpected findings, and indicate what the next steps might be. Do not refer to every detail of your work again; repeating the Results section in the Discussion is a common mistake of inexperienced writers. Another common mistake is to add another Introduction. Instead, in your Discussion, summarize and generalize.

Adjust your Discussion according to who your potential readers will be and make it no longer than necessary. If you are writing for a very specific group of people, stay within their area of interest. If you are writing for a broad audience, you probably need to discuss much broader implications and provide more generalizations and background.

In general, know that in the related fields of biology and medicine, basic scientists and clinicians read each other's papers. So if you write your paper primarily for a scientific audience, do not ignore the clinical implications of your results; and if you are addressing a clinical audience, try to discuss the scientific significance as well. In this way, your work will have much greater impact.

### 13.3 ORGANIZATION

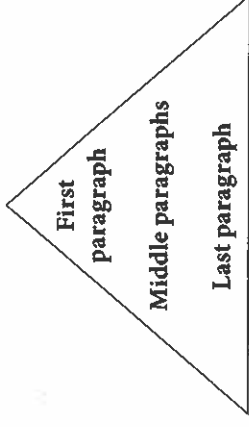
#### DISCUSSION GUIDELINE 4:

Organize the Discussion in a *pyramid structure*:

- First paragraph: Interpretation/Answer based on key findings  
Supporting evidence
- Middle paragraphs: Comparisons/Contrasts to previous studies  
Limitations of your study  
Unexpected findings  
Hypotheses or models
- Last paragraph: Summary  
Significance/Implication

Opposite of the Introduction, which follows a funnel shape, the Discussion follows a pyramid shape. In other words, it moves from specific to general.

The pyramid structure of the Discussion can be divided into



In the first paragraph, tell your readers what your key findings were and what they mean. In subsequent paragraphs, explain how your findings fit into what is known in the field. In the last paragraph, summarize and generalize why the contribution of your study is important overall, in your field, outside your field, and/or for society.

A more detailed explanation of this organizational structure is provided in the next subsections of this chapter.

### 13.4 FIRST PARAGRAPH

Begin the Discussion with an interpretation of the key finding(s), which present the answer to the question posed in the Introduction. Then support your answer by stating the relevant results, providing explanations, and/or other data. Do not assume that the reader has memorized the results or will search for them. You have to put the story together for the reader.

Because the interpretation of your key findings is the most important statement in the paper, it should appear in the most prominent position: the first paragraph of the Discussion. The interpretation of your key findings should match the question/purpose for the study stated in the Introduction and answer what the introduction asked. The interpretation of your key findings should also be repeated in the other power position of this section: the last paragraph.

Do not begin the Discussion with a second introduction, a summary of the results, or secondary information. Begin by directly stating the answer based on your findings in the opening sentence of the Discussion. If you feel this beginning is too abrupt, you can restate the purpose of the study or provide a brief context before stating the answer. Any statements placed before your answer should not exceed more than a few sentences.

If your answer is in the first paragraph of the discussion, the reader is sure not to miss it. Readers typically do not read the whole paper front to back. Rather, they skim over the Abstract, maybe read the Introduction, and then immediately jump to the Discussion. In the Discussion, readers instantly want to find the answer to the research question, that is, the interpretation of the key findings of the study. Readers do not usually take the time to read the whole Discussion. They will typically read the first paragraph and then go on to the last paragraph. Thus, your key findings and their interpretation(s) should be placed in these two power positions.

**Example 13-1** First paragraph of Discussion**Question/Purpose:**

Effectiveness of Peridomestic Lyme Disease Protection Measures

**Answer/Interpretation of key findings:**

Our findings emphasize the need to continue to promote personal protection measures to reduce the risk of Lyme disease infection. We have identified three reasonable personal measures that may be protective against Lyme disease when practiced: tick checks, bathing, and insect repellents. Performing tick checks within 36 hr after spending time in the yard may reduce one's risk by as much as 46%. In addition, bathing may reduce one's risk by up to 57%, and the use of insect repellent may be protective against the disease up to 75%.

Supporting evidence

(With permission from Neela Connolly)

In Example 13-1, the interpretation of the key findings matches the purpose of the study. Note that the same key terms (*protection*, *measures*, *Lyme disease*) appear in the question/purpose as well as in the interpretation or answer to the question. This answer is immediately supported by key findings of the study.

Here is another example:

**Example 13-2****First paragraph of Discussion****Question/Purpose:**

Our goal was to determine what part of the bindin polypeptide is responsible for the species-specific egg agglutination activities of the protein.

**Answer/Interpretation of key findings:**

Our results suggest that the part of bindin responsible for species-specific egg agglutination lies in the region of residues 75-121. We showed that residues 18-74 and 122-236 can be deleted without loss of egg agglutination activity. All of the biologically active bindin deletion analogs were found to be species-specific by their ability to agglutinate exclusively *S. purpuratus* eggs. Deletion analogs that had any residues of region 75-121 deleted exhibited no significant activity above the bacterial control protein.

Supporting evidence

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In this example, the answer also matches the question/purpose posed. Note the *signals* used to guide the reader through the answer and supporting evidence in both of the previous examples. Note also the different verb tenses. To distinguish between results and the conclusions you draw from them, use the past tense for results (“showed,” “were found,” “exhibited”) and present tense for general statements, interpretations, and conclusions (“suggest”).

The exception to beginning the Discussion with an interpretation of the key findings is for papers that describe controversial topics and findings. For highly controversial topics, argue your case first by presenting your findings and explaining differences from other findings. This organization will help to logically prepare the reader for your upcoming argument. Present the controversial interpretation of your key findings at the end of the Discussion in these papers.

### 13.5 MIDDLE PARAGRAPHS

#### DISCUSSION GUIDELINE 5:

Organize the topics according to the science or from most to least important.

#### DISCUSSION GUIDELINE 6:

Compare and contrast your findings with those of other published results.

#### DISCUSSION GUIDELINE 7:

Explain any discrepancies, unexpected findings, and limitations.

#### DISCUSSION GUIDELINE 8:

Provide generalizations where possible.

In this part of the discussion, it is not only important to put your findings in the context of your field but also to make connections to other important implications of the work or to other seemingly related or perhaps unrelated fields.

After stating and supporting your answer, mention other findings that were important. Tell your readers what you think your results mean and how strongly you believe in them. Organize these findings according to the science or from most to least important. To ensure that your

Discussion is organized rather than rambling, focus the story on the question/purpose of the paper that was stated in the Introduction.

Treat your secondary results as you did your main findings: Summarize and generalize them rather than simply repeating what you found. Do not discuss every single result you obtained. Rather, list and explain any general trends and tendencies and evaluate these.

The presentation of your arguments is a matter of personal style as is the order of the paragraphs between the first and last paragraph. To develop the middle paragraphs of a Discussion, organize the topics by proceeding from most to least important unless there is a reason for putting one topic before another. Explain any new findings and concepts obtained in your study, but do not present any new data that has not already been mentioned in the Results section. Also, do not repeat any information that has already been presented in other sections of your paper.

Mention any limitations of your study or unexpected findings, and present any new hypothesis or model based on your findings. If useful, include figures to illustrate complex models in the discussion. Compare and contrast your findings with those of previously published papers, but avoid the temptation to discuss every previous study in your subject area. Stick to the most relevant and most important studies. Explain any disagreements objectively, and credit and confirm the work of others. Give pro and contra arguments for your conclusion. Only if you mention both impartially will you sound convincing to the reader. Know that most of the time it is wise to present your opinion carefully rather than too strongly.

### Comparisons and Contrasts

In addition to stating and supporting your answer, you need to explain how your findings fit in with existing knowledge on the topic. You can do so by comparing and contrasting your results with those found by others. One way to get started in comparing and contrasting your findings and interpretations is to prepare lists that contain your findings and those of others. Based on lists like these, you may be better able to see and discuss any similarities or differences between your work and that of previous reports.

When you mention any results that do not support your answer and conclusions, explain these findings as best as you can. If you can explain why a finding is conflicting, it is almost always worth doing so. If you cannot explain these findings, say so (“We cannot explain why . . . .” “Although the reason for X is not obvious, . . .”).

See the following example for an explanation of contrasting findings. In this example, the authors discuss a finding of another study that differs from the answer to their question (“In contrast to our observations . . .”). The authors then discuss why previous findings cannot be directly compared with their results and go on to explain how previous studies had obtained these conflicting results.

### Example 13-3

#### Comparing and contrasting findings in the Discussion

We observed virtually no size classes of mtDNA molecules. Since the undegraded circular mtDNA molecules were entirely of heterogeneous size, this observed size heterogeneity probably reflects the real situation within plant mitochondria. . . . *In contrast to our observations*, size classes of linear or circular molecules and species specific differences have been previously reported (24, 25). However, these studies were performed only with a fraction of supercoiled DNA (26), which most likely does not represent the complete set of molecules existing in *organello*. Supercoiled DNA isolated from a *C. album* suspension culture, for example, consisted exclusively of small circular plasmid mp1 DNA. Its oligomers were found in the open circular form, thus appearing indeed as a few size classes.

(With permission from Springer)

Finding of paper  
Signal for contrasting finding

Explanation of conflict

Example 13-4 provides another example of comparing and contrasting findings and ideas in a Discussion:

### Example 13-4

#### Comparing and contrasting findings in the Discussion

The frequency of targeted events among integrative transformants was about 30% for transformation with a vector that shares 1 kb of sequence homology with the genome. This targeting efficiency is comparable to that reported for insertion vectors sharing more than 2 kb of sequence homology with the moss genome (16). However, a targeting efficiency of 30% using 1 kb of genomic sequence is considerably higher than that previously observed in higher plants (0.13%) (18). The requirement for sequence homology for homologous recombination appears therefore to be stringent and comparable to that reported for mouse embryonic stem cells (37).

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Finding of paper

Comparison to other study

Contrasting finding

Comparison to other study

### Limitations

Limitations of the study as well as assumptions should be explained in the Discussion, especially if their explanations are too long to be placed into the Materials and Methods section.

**Example 13-5 Explaining limitations in the Discussion**

Our data show that A $\beta$  assemblies did not colocalize in drusen. It is important to note, however, that the epitope for A $\beta$  may have been masked within the oligomeric structure, as is the case when A $\beta$  monomers are transformed into amyloid fibrils (40). Therefore, we cannot preclude the possibility that the oligomeric cores in drusen are made up of A $\beta$ .

Limitation

**Unexpected Findings**

Aside from comparing and contrasting your work with that of previous studies and describing limitations in your study, unexpected findings may also be mentioned in the Discussion section. Be alert to unexpected findings. Do not automatically assume that your experiment failed or that you made a mistake. Unexpected findings may be important—they may lead to new discoveries and alter the focus of your study.

When describing an unexpected finding, state at the beginning of the paragraph that the finding was unexpected (or surprising), and then explain it as best you can.

**Example 13-6 Describing unexpected findings**

*To our surprise* we discovered that the bindin fusion protein was being cleaved during isolation and purification. The proteolysis is remarkably efficient since only small amounts of the unprocessed form remain (Fig. 2, lane 3). We purified the cleaved bindin product to homogeneity by reverse phase HPLC and sequenced it to determine the site of cleavage. The predominant product is the mature bindin polypeptide containing an additional 4 amino acids of probindin and a minor product that corresponds to bindin containing a single additional amino acid. Both products contain arginine as the N-terminal amino acid. These results suggest that the fusion protein is cleaved at two sites: the Arg-Arg junction between the factor Xa linker and the probindin coding sequence and within the probindin segment at the Lys-Arg junction.

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Description of unexpected finding

**Generalizations**

Sometimes you may be able to generalize your findings and formulate a hypothesis or propose a possible model. Explain how you arrived at your hypothesis or model. Consider illustrating complex models in figures. Describe how the hypothesis or the model works, incorporating a

discussion of any figures if needed. If possible, also describe ways to validate your model.

**Example 13-7 Formulating hypotheses**

We found that the substrate [ $^3\text{H}$ ]-[9R]iP moves into the cells where it does not accumulate to concentrations higher than in the medium. However, the mechanism of [ $^3\text{H}$ ]-[9R]iP uptake is unclear. Because no extracellular activities for the deribolisation of [ $^3\text{H}$ ]-[9R]iP could be detected, we hypothesize that it is metabolized intracellularly to [ $^3\text{H}$ ]-iP and that the bidirectional transport of iP is based on passive diffusion.

Hypothesis

Following is another example that explains a hypothetical model the authors came up with and points to a figure of this model:

**Example 13-8 Formulating a hypothetical model**

Repeated elements located in the amino- and carboxyl-terminus of the protein X vary in sequence for the different species tested. A hypothetical model of how these repeated elements might interact with the egg receptors is shown in Fig. 7. In this model, protein X is able to interact with complementary sites on its own receptor but not with those of a different species. Protein Y on the other hand contains ligands that interact not only with its own receptor but also with that of another species. This model can explain the unidirectionality in cross fertilization.

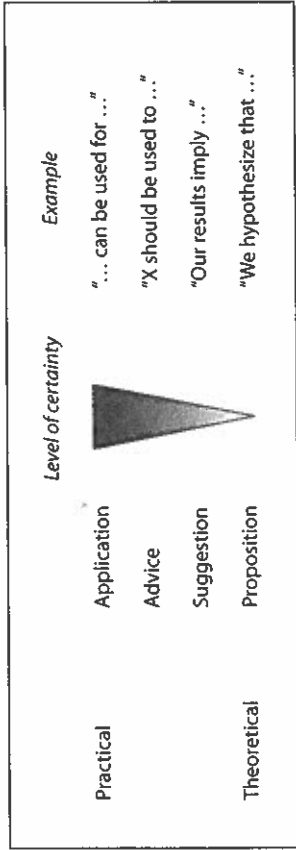
Hypothetical model and figure

**13.6 LAST PARAGRAPH**

At the end of the discussion, you should provide some closure by writing a one paragraph concluding summary. Readers typically expect to see two things in the summary of a scientific paper: an analysis of the most important results and the significance of the work. The analysis of the most important results is typically provided by the interpretation of your key findings, that is, the answer. Here too, the answer should match the question/purpose you posed in the Introduction and the answer presented in the first paragraph of the Discussion. Do not bring in new evidence for the summary. Rather, complete the “big picture” by restating your answer, that is, the interpretation of the key findings.

The significance of the work can be provided by including far-reaching interpretations and conclusions at the end of the Discussion section. Try to generalize your specific findings to other broader situations. Depending on your level of certainty, significance can range from the

practical application to the theoretical proposition. Adding a practical application, giving advice, implying an action, or providing a proposition in the concluding paragraph gives the paper importance. Discuss any theoretical implications, possible applications, recommendations, or speculations based on your findings. If you pose any speculations or implications, base them on solid evidence and make sure that the reader understands that these are your speculations or implications.



Because the conclusions are the major message of your paper, you should phrase them with great care. Possible ways to provide some closure of your work at the end of the Discussion section are shown in the next examples:

**Example 13-9 Concluding paragraph with application**

<b>Answer</b>	<i>In summary, our work reveals the functional interactions involved in the binding of antibiotics to the peptidyl transferase cavity of the bacterial ribosome. None of the antibiotics examined show any direct interaction with ribosomal proteins. Chloramphenicol targets mainly the A site, where it interferes directly with substrate binding. Clindamycin interferes with the A site and P site substrate binding and physically hinders the path of the growing peptide chain. Macrolides bind at the entrance to the tunnel where they sterically block the progression of the nascent chain. The structural model of the peptidyl transferase center in complex with the examined antibiotics can not only enable a rational approach for antibiotic development and therapy strategies but can also be used to identify new target sites on the eubacterial ribosome.</i>
<b>Key findings</b>	
<b>Significance indicated by a possible application</b>	<i>(With permission from Macmillan Publishers Ltd.)</i>

In this example, "In summary, ..." signals the conclusion. The first sentence of the paragraph is at the same time the topic sentence and the answer to the question. The word "can" in the last sentence indicates the importance of the work by signaling an application.

Other signals for a concluding paragraph are "Taken together, ..." or "In conclusion, ..." (see also Section 13.8), or the subheading "Conclusion." Sometimes, even an overall, summarizing question can serve as the signal of the concluding paragraph.

If you have drawn conclusions different from your original hypotheses, you might suggest ways in which these conclusions could be verified in future research. Do not merely say, however, that future research will be needed to clarify the issues without giving the reader any indication of what form this research might take.

The next example shows a conclusion that includes a speculation. This speculation is signaled by the words "believe" and "may."

**Example 13-10 Conclusion with speculation and future direction**

<b>Signal of conclusion</b>	In summary, we found no statistically significant associations between increased homocysteine (HCY) and age-related macular degeneration (AMD) after analyzing a large and well-characterized population of patients with and without maculopathy from two geographic areas in the United States. An analysis of smoking and HCY fertile subgroups did not show any association between smoking, increased HCY, and increased risk of intermediate or advanced AMD. An association between homocysteine levels and an increased risk of intermediate or advanced AMD may exist for patients for whom HCY is above the 90th percentile of HCY, as these patients were more likely to have intermediate or advanced AMD. When subjected to statistical analysis, this observation was found to be not significant however, and only a larger study cohort could determine whether there is any true association.
<b>Answer</b>	
<b>Key findings and Conclusions</b>	
<b>Future direction</b>	

**13.7 IMPORTANT WRITING PRINCIPLES FOR THE DISCUSSION**

**Tone**

The tone of your writing is important. "Beginners" often do very good scientific work but are intimidated by the knowledge and work of "experts." However, when you have collected enough data and are presenting your findings in a paper, you become an expert too. Make your writing convey very confidence and authority. Show that you are knowledgeable about the subject, and take responsibility for your conclusions. Do not be afraid to take a stand.

Often ESL authors are also intimidated but mainly because English is not their native language. Some ESL authors do not realize when they sound too opinionated and their language use is too strong. Ask a native speaker, preferably a scientific editor, to read over your manuscript.

ESL advice