Teaching Scientific Writing

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The following material was developed for the teaching the scientific communications component of 7.02 Introduction to Molecular Biology and Communication, a class required of all biology majors at MIT and one that fulfills the institute's communication-intensive requirement. The objectives of the class are as follows:

By the end of the term, students will be able to:

- Understand the seven components (title, abstract, introduction, methods, results, discussion/conclusion, tables/figures) of a laboratory research paper.
- Understand the writing process and its application to scientific writing.
- Understand the importance of communicating in writing as a scientist.
- Apply an understanding of scientific writing to their subsequent independent research.

To help students achieve these goals, the class meets six times over the semester with each meeting focusing on a different component of the scientific research article: 1. Introduction, 2. Methods, 3. Results, 4. Illustrations, 5. Discussion/Conclusion, 6. Title/Abstract. Students complete in-class writing activities, out-of-class writing and peer-review and a long-term recursive writing project based on students' choice of several scientific options.

For PowerPoint slides with more detailed content and examples, go to
http://web.mit.edu/nlerner/Public/ScientificCommunication.ppt (27 MB file)

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Introductions

What's an Introduction?

- An introduction is a method to ***familiarize and orient*** your readers.
- The content of an introduction depends on its ***purpose*** and the ***audience***.
- All models share a ***direct approach***. Don't hide your main point or save it until the end of the paper.

What's the Purpose of an Introduction in Scientific Writing?

- Provide the ***context*** of your work (create your research space, define gap in knowledge, set up the direction you'll take in your discussion section).
- State your ***focus*** (hypothesis, question).
- Provide ***justification*** for your work (how your work can answer the question).

CARS Model (Swales)

Create **a** **R**esearch **S**pace

1. Re-establish significance of research field.
2. Situate actual research in these terms.
3. Show how this niche will be occupied and defended.

What are Some Common Pitfalls of an Introduction Section?

- Including ***unnecessary background*** or being repetitive.
- ***Exaggerating*** (or understating) the importance of your work.
- Using ***lackluster*** openers and ***weak*** follow-through in the body of your introduction.
- Not grounding the work in a ***context*** that will be important to your reader.
- Not ***focusing*** on a clear and compelling research question or hypothesis.

Guidelines for Introductions from Two Scientific Organizations

From the International Committee of Medical Journal Editors:
State the purpose of the article and summarize the rationale for the study or observation. Give only strictly pertinent references and do not include data or conclusions from the work being reported.

From the American Society for Microbiology:
The introduction should supply sufficient background information to allow the reader to understand and evaluate the results of the present study without referring to previous publications on the topic. The introduction should also provide the hypothesis that was addressed or the rationale for the present study. Use only those references required to provide the most salient background rather than an exhaustive review of the topic.

Methods

What are Some Goals of a Methods Section?

- Present the **experimental design.**
- Provide enough detail to allow readers to **interpret your results**.
- Give enough detail for readers to **replicate** your work.

  "The key to a successful Methods section is to include the right amount of detail--too much, and it begins to sound like a laboratory manual; too little, and no one can repeat what was done." *Successful Scientific Writing, 2nd ed.*

What are Some Pitfalls of a Methods Section?

- Providing **too little or too much** information.
- **Reiterating** published methods rather than citing them.
- Writing strictly in **chronological order** (alternatives: most important first, most fundamental first, etc.).
- Methods and results don't **correspond** (you have to provide methods for all the experiments you report).
- **Forgetting to use visual organizers** that direct readers to specific aspects of the methods section, e.g., subheads.
- Using a "dangling modifier" because of an over-reliance on passive voice:

  "After scraping the desired plate in four swipes, the bacteria were placed in 8ml of media with no antibodies."
- Failing to provide a context for the methods themselves:

  "In order to . . . , we . . . " ⇐ context for the particular method is provided.
- Writing a Protocol rather than a Methods section.

A Protocol is . . .
A series of steps to be carried out.
Written in sequential or temporal order.
Intended for the reader to achieve a final result.
A Methods Section is . .
A series of steps already completed and is written in past tense.
Written in logical order.
Intended for the reader to replicate the experiment.

Results

What is the Purpose of the Results Section?

- **Objectivity**: Make the data, just the data, easy to find.
  Some readers want to interpret your data themselves rather than accepting the interpretation presented in the discussion.
- **Description**: Describe the data presented in figures and tables.

What Differentiates Results from the Methods?

- Methods = *How* the data were accumulated.
- Results = *What* data were accumulated.

What Differentiates Results from the Discussion?

- Results = Data *presentation* ("Experiments showed that . . . .")
- Discussion = Data *interpretation* ("Experiments suggest that . . . .")

What are the Contents of a Results Section?

- A brief description of the experiment or rationale at the beginning of each subsection ("In order to . . . . As a result, we found that . . . .).
- The data (in past tense).
- Descriptive text for FEW determinations.
- Tables or graphs for REPETITIVE determinations.
- The data that your methods indicated you would produce (and answering the questions you established in your introduction).

What are Some Qualities of a Well-Written Results Section?

- Methods and Results **Correspond**.
  i.e., no experimental results for which there are no methods, and vice versa.
- Results are presented in a **logical order**.
  e.g., most important first, most fundamental first, etc.
- Results **focus on the question(s) or hypothesis** introduced earlier in the paper.

What are Some Pitfalls of a Results Section?

- **Overstating** the results (e.g., "Figure 1 clearly shows…")
- Reporting **irrelevant** results: Although it is sometimes useful to report experiments that didn't work.

- **Omitting** visual organizers, such as subheads.
- Including **inappropriate** illustrations.
- Including methods and/or discussion: Overlap is acceptable in some circumstances.

Results Example 1: Creating a context for the results

Results

I hypothesize that CG7593 acetylates certain lysine residues of the histone protein, therefore neutralizing them, disrupting histone-DNA interaction, and allowing HeT-A to bind to telomeric DNA. CG7593 may or may not be involved in directing HeT-A to the telomeres. According to the hypothesis, I expect that CG7593 localizes in the nucleus and that in its absence, the entry of HeT-A into the nucleus would not be affected. The first steps in performing the experiments to test the hypothesis were verifications of HeT-A-GFP construct to be transfected into Schneider 2 cells, SD10812 EST from which *CG7593* was amplified, and the created *CG7593* dsRNA.

HeT-A-GFP construct verification SD10812 EST verification
_CG7593_ dsRNA verification
HeT-A protein localization in _CG7593_ knock down Schneider 2 cell cultures
Viability Analysis

Results Example 2

RESULTS

Pendulin and HeT-A were previously shown to interact in a yeast 2-hybrid screen. Pendulin encodes importin-α, which is involved in the translocation of proteins through the nuclear pore (Quimby and Corbett, 2001). The possible role of pendulin in the localization of HeT-A to the nucleus was studied via visualization of HeT-A with fluorescence microscopy and RNAi inhibition of pendulin translation in S2 cells.

HeT-A Verification
HeT-A Expression in S2 cells
EST Verification
Effect of RNAi on HeT-A expression in S2 cells
Production and Transfection of GFP:Pendulin Construct
Production and Transfection of Truncated GFP:Pendulin Deletion Derivatives
Estimation of Cell Viability
RT-PCR

Illustrations

What's the Purpose of Illustrations?

- **Condense** large amounts of information
- **Convince** readers of your findings (by showing data quality).
- **Focus attention** on certain findings (e.g., relationship between values).
- **Simplify** complex findings.
- **Promote** thinking and discussion**.**

***Illustration Caveat**: The most beautiful illustration cannot hide lousy content--content is key.*

What are Some Pitfalls of Figures and Legends?

Figures

- Not mentioned in text.
- Textual data inconsistent with figures.
- Mislabeling.
- Symbols, data points, unreadable or cluttered.
- Ugliness (failure to get help from graphic designer).

Legends

- Reiterate results section
- Written in shorthand, abbreviated form rather than whole sentences.

Choose the Most Effective Type of Illustration for a Given Goal

(from *Successful Scientific Writing*, 2nd ed.)

To accomplish this:	**Choose one of these**:
To present exact values, raw data, or data which do not fit into any simple pattern.	Table, list
To summarize trends, show interactions between two or more variables, relate data to constants, or emphasize an overall pattern rather than specific measurements.	Line graph
To dramatize differences or draw comparisons.	Bar graph
To illustrate complex relationships, spatial configurations, pathways, processes, or interactions.	Diagram
To compare or contrast.	Pictograph, pie chart, bar graph

Choose the Most Effective Type of Illustration (cont.)

To accomplish this:		**Choose one of these:**
To show sequential processes	⇐---------⇒	Flowchart
To classify information	⇐---------⇒	Table, list, pictograph
To describe parts or circuits.	⇐---------⇒	Schematic
To describe a process, organization, or model.		Pictograph, flowchart, block diagram
To describe a change of state.	⇐---------⇒	Line graph, bar graph
To describe proportions.	⇐---------⇒	Pie chart, bar graph
To describe relationships.	⇐---------⇒	Table, line graph, block diagram
To describe causation.	⇐---------⇒	Flowchart, pictograph
To describe an entire object.	⇐---------⇒	Schematic, drawing, photograph
To show the vertical or horizontal hierarchy within an object, idea, or organization.	⇐---------⇒	Flowchart, drawing tree, block diagram.

Provide Textual Context for Your Illustrations

In the body of your article:

- Refer explicitly to the illustration (e.g., "see Table 1," "refer to Figure 3.")

Tell the reader:

- How the graphic advances, supports, clarifies, or summarizes your discussion.
- Why it is important.
- What it means.
- How it supports your argument.

Examples of Effective Titles/Legends

Figure 1. Initial velocity vs. ONPG substrate concentration for His461. ONPG was added to β-galactosidase extracted from *E. coli* His461. The initial rates were measured using spectrophotometer A_{420} readings.

Table 1. Increase of Initial Velocity with Increase of Enzyme Concentration. As the concentration of the enzymes His461 and CSH36 are increased, the rate of A_{420} reading increases, as does the initial velocity (in nmol ONP/ml/min).

Figure 1. Optical density readings at 595nm at four known concentrations. The best-fit line is drawn to determine the protein concentration of samples with known optical densities.

Discussion/Conclusion

What is the Purpose of a Discussion Section?

- **Summarize findings** presented in the results section
- **Cite supporting literature**.
- **Explain discrepancies** between your findings and previous reports.
- Point out **shortcomings** of your work and define unsettled points.
- Discuss **theoretical and practical implications** of your work.
- End with a short **summary or conclusion** about the work's importance.

Questions You Will Address in a Discussion Section

- What did you expect to find, and why?
- How did your results compare with those expected?
- How might you explain any unexpected results?
- How might you test these potential explanations?

Tips for Writing a Discussion Section

"This is the place to interpret your results against a background of existing knowledge. Explain what is new in your work, and why it matters. Discuss both the limitations and the implications of your results, and relate observations to other relevant studies. State new hypotheses when warranted, clearly labeled as such. Include recommendations, when appropriate."

Eight Common Components of a Discussion Section (Swales)

- Background information
- Statement of results

- (Un)expected outcome
- Reference to previous research
- Explanation
- Exemplification
- Deduction and Hypothesis
- Recommendation

What is the Purpose of a Conclusion?

"Besides presenting an analysis of the key results in the conclusion sections, you also give a *future perspective* on the work. In some documents that future perspective might be recommendations. In other documents that future perspective might be a nod to the direction in which your research will head. A third kind of future perspective is to mirror the scope and limitations that you presented in the beginning of the document."

What are the Pitfalls of a Discussion/Conclusion Section?

- Including **too much information** (wordy arguments, not focused, meandering, etc.).
- **Failure to follow** arguments set up in the **introduction**.
- **Failure to** focus on the **current results.**
- **Speculating** too much or not enough.
- **Improper tense** (Discussion largely in present tense).
- **Hedging** excessively.

Excessive Hedging

"The cause of the degenerative changes is unknown but *possibly* one cause *may* be infection by a *presumed* parasite."

Rule of thumb: One hedge word per sentence!

Titles/Abstracts

What is the purpose of an abstract?

- A stand alone, mini-version of the paper (250 words or less).
- Summarizes the main sections of the paper.
- States the purpose, findings, and impact of the work.

Abstracts: The Goal is an Economy of Words

- Provide an abstracted version of your paper in as few words as possible.
- Choose each word carefully. Make them clear and significant.
- Provide only the key points.

Language: Needless Words in parentheses

(already) existing	Mix (together
At (the) present (time)	Never (before)
(basic) fundamentals	None (at all)
(completely) eliminate	Now (at this time)
(continue to) remain	Period (of time)
(currently) being	(private) industry

(currently) underway	(separate) entities
(empty) space	Start (out)
Had done (previously)	Write (out)
Introduced (a new)	(still) persists

What are Some Pitfalls of Abstracts?

- Contains extraneous detail or information or conclusions not stated in the paper.
- Contains abbreviations, chemical formulas, jargon or references to the literature, tables, or figures.
- Failure to state the purpose of the work at the outset.
- Failure to state the importance of the work and where it leads at the end.

What is the Purpose of a Title?

- Indicate the **subject** of your research.
- **Distinguish** your research from others of its kind.
- **Show continuity** with preceding papers.
- Provide **key words** for indexing.

The Importance of Titles

"The title is the single most important phrase of a scientific document. The title tells readers what the document is. If your title is inexact or unclear, many people for whom you wrote the document will never read it."

What are Some Pitfalls of Titles?

- Too general or too specific.
- Too long or too short.
- Incomprehensible (sometimes from the use of jargon).
- Inaccurate (often a syntax problem).
- Contains abbreviations, chemical formulas, jargon.

Some Bad Titles (from *Science of Scientific Writing*, 2nd ed.)

- Plantar's Wart Removal: Report of a Case of Recurrence of Verruca after Curative Excision
- Characteristics of Columbine Flowers are Correlated with Their Pollinators
- Panda Mating Fails: Veterinarian Takes Over
- Gleanings on the Bionomics and Behavior of the East Asiatic Nonsocial Wasps. III. The Subfamily Crabroninae with a Key to the Species of the tribe Crabronini Occurring in Formosa and the Ryukyus, Contributions to the Knowledge of the Behavior of Crabronine Fauna, and Changes in the Taxonomic Position of Three Species of Crabronini Occurring in Japan
- Report of New Health Data Results from the 1999 National ASAP-FYI-ERGO Health Study: Lung Cancer in Women Mushrooms

Some Good Titles

- Effect of Husband's Education on the Fatness of Wives
- Retrotransposons as Engines of Human Bodily Transformation
- Enhanced Recovery of Bitumen by Steam with Chemical Additives

- Adaptive Nulling in the Hyperthermia Treatment of Cancer