CHAPTER 12

How to Write the Results

Results! Why, man, I have gotten a lot of results. I know several thousand things that won't work.

—Thomas A. Edison

CONTENT OF THE RESULTS

So now we come to the core of the paper, the data. This part of the paper is called the results section.

Contrary to popular belief, you shouldn't start the results section by describing methods that you inadvertently omitted from the materials and methods section.

There are usually two ingredients of the results section. First, you should give some kind of overall description of the experiments, providing the big picture without repeating the experimental details previously provided in materials and methods. Second, you should present the data. Your results should be presented in the past tense. (See "Tense in Scientific Writing" in Chapter 30.)

Of course, it isn't quite that easy. How do you present the data? A simple transfer of data from laboratory notebook to manuscript will hardly do.

Most importantly, in the manuscript you should present representative data rather than endlessly repetitive data. The fact that you could perform the same experiment 100 times without significant divergence in results might be of considerable interest to your major professor, but editors, not to mention readers, prefer a little bit of predigestion. Aaronson (1977, p. 10) said it another way: "The compulsion to include everything, leaving nothing out, does not prove that one has unlimited information; it proves that one lacks discrimination." Exactly the same concept, and it is an important one, was stated almost a century earlier

by John Wesley Powell, a geologist who served as president of the American Association for the Advancement of Science in 1888. In Powell's words: "The fool collects facts; the wise man selects them."

HOW TO HANDLE NUMBERS

If one or only a few determinations are to be presented, they should be treated descriptively in the text. Repetitive determinations should be given in tables or graphs.

Any determinations, repetitive or otherwise, should be meaningful. Suppose that, in a particular group of experiments, a number of variables were tested (one at a time, of course). Those variables that affect the reaction become determinations or data and, if extensive, are tabulated or graphed. Those variables that do not seem to affect the reaction need not be tabulated or presented; however, it is often important to define even the negative aspects of your experiments. It is often good insurance to state what you did *not* find under the conditions of your experiments. Someone else very likely may find different results under different conditions.

If statistics are used to describe the results, they should be meaningful statistics. Erwin Neter, who was editor in chief of *Infection and Immunity,* told a classic story to emphasize this point. He referred to a paper that reputedly read: "33 1/3% of the mice used in this experiment were cured by the test drug; 33 1/3% of the test population were unaffected by the drug and remained in a moribund condition; the third mouse got away."

STRIVE FOR CLARITY

The results should be short and sweet, without verbiage. Mitchell (1968) quoted Einstein as having said, "If you are out to describe the truth, leave elegance to the tailor." Although the results section is the most important part, it is often the shortest, particularly if it is preceded by a well-written materials and methods section and followed by a well-written discussion.

The results need to be clearly and simply stated because it is the results that constitute the new knowledge that you are contributing to the world. The earlier parts of the paper (introduction, materials and methods) are designed to tell why and how you got the results; the later part of the paper (discussion) is designed to tell what they mean. Obviously, therefore, the whole paper must stand or fall on the basis of the results. Thus, the results must be presented with crystal clarity.

AVOID REDUNDANCY

Do not be guilty of redundancy in the results. The most common fault is the repetition in words of what is already apparent to the reader from examining the figures and tables. Even worse is the actual presentation, in the text, of all or many of the data shown in the tables or figures. This grave sin is committed so frequently that it is commented on at length, with examples, in the chapters on how to prepare tables and illustrations (Chapters 16 and 17).

Do not be verbose in citing figures and tables. Do not say, "It is clearly shown in Table 1 that nocillin inhibited the growth of *N. gonorrhoeae*." Say, "Nocillin inhibited the growth of *N. gonorrhoeae* (Table 1)." The latter format has multiple benefits. Because it is briefer, it helps authors comply with journals' word limits. It also is more readable. It also directs attention to what is most important: the findings, not the table or figure.

Some writers go too far in avoiding verbiage, however. Such writers often fail to provide clear antecedents for pronouns, especially "it." Here is an item from a medical manuscript: "The left leg became numb at times and she walked it off. . . . On her second day, the knee was better, and on the third day it had completely disappeared." The antecedent for both "its" is presumably "the numbness," but the wording in both instances seems a result of dumbness.

A SUPPLEMENT ON SUPPLEMENTARY MATERIAL ONLINE

Increasingly, journals are electronically posting material supplementary to papers being published. Although sometimes this material regards methods, most commonly it provides information about the results. For example, additional data may be posted, or additional tables and figures may be provided online. Whether authors may submit such supplementary material, and if so how, varies among journals. Also, norms regarding what supplementary materials to provide online vary among research fields. If you think that providing supplementary material for online posting would be desirable, consult the instructions to authors of your target journal. If possible, also see what papers analogous to yours have done in this regard. Keep in mind, too, that the journal editor may ask you to place some of your material in an online supplement.

CHAPTER 13

How to Write the Discussion

It is the fault of our rhetoric that we cannot strongly state one fact without seeming to belie some other.

—Ralph Waldo Emerson

DISCUSSION AND VERBIAGE

The discussion (which some journals term a comment, especially for short papers) is harder to define than the other sections. Thus, it is usually the hardest section to write. And, whether you know it or not, *many* papers are rejected by journal editors because of a faulty discussion, even though the data of the paper might be both valid and interesting. Even more likely, the true meaning of the data may be completely obscured by the interpretation presented in the discussion, again resulting in rejection.

Many, if not most, discussion sections are too long and verbose. As Doug Savile said, "Occasionally, I recognize what I call the squid technique: the author is doubtful about his facts or his reasoning and retreats behind a protective cloud of ink" (*Tableau,* September 1972). Another reason some discussions are long and hard to follow is that many authors think they must avoid first person. If you mean "I found that . . ." or "We conclude that, . . ." say so. Try to avoid wordier, and sometimes more ambiguous, constructions such as "It was found in the present investigation that . . ." and "It is concluded that."

Some discussion sections remind one of the diplomat, described by Allen Drury in *Advise and Consent* (Garden City, NY: Doubleday, 1959, p. 47), who characteristically gave "answers which go winding and winding off through the interstices of the English language until they finally go shimmering away altogether and there is nothing left but utter confusion and a polite smile."

COMPONENTS OF THE DISCUSSION

What are the essential features of a good discussion? The main components will be provided if the following injunctions are heeded.

1. Try to present the principles, relationships, and generalizations shown by the results. And bear in mind, in a good discussion, *you discuss—you do not recapitulate*—the results.
2. Point out any exceptions or any lack of correlation and define unsettled points. Never take the high-risk alternative of trying to cover up or fudge data that do not quite fit.
3. Show how your results and interpretations agree (or contrast) with previously published work.
4. Don't be shy; discuss the theoretical implications of your work, as well as any possible practical applications.
5. State your conclusions as clearly as possible.
6. Summarize your evidence for each conclusion. Or, as the wise old scientist will tell you, "Never assume anything except a 4-percent mortgage."

Much as the methods and the results should correspond to each other, the introduction and the discussion should function as a pair. At least implicitly, the introduction should have posed one or more questions. The discussion should indicate what the findings say about the answers. Failure to address the initial questions commonly afflicts discussions. Be sure the discussion answers what the introduction asked.

Whereas the content of the introduction commonly moves from the general topic to your specific research, in sort of a funnel format, the discussion tends to do largely the reverse, much like an inverted funnel. For example, a well-structured discussion may first restate the main findings, then discuss how they relate to findings of previous research, then note implications and applications, and perhaps then identify unanswered questions well suited for future research. In the introduction, you invited readers into your research venue; in the discussion, you usher them out, now well informed about your research and its meaning.

FACTUAL RELATIONSHIPS

In simple terms, the primary purpose of the discussion is to show the relationships among observed facts. To emphasize this point, the story may be told about the biologist who trained a flea.

After training the flea for many months, the biologist was able to get a response to certain commands. The most gratifying of the experiments was the one in which the professor would shout the command "Jump," and the flea would leap into the air each time the command was given.

The professor was about to submit this remarkable feat to posterity via a scientific journal, but he—in the manner of the true scientist—decided to take his experiments one step further. He sought to determine the location of the receptor organ involved. In one experiment, he removed the legs of the flea, one at a time. The flea obligingly continued to jump upon command, but as each successive leg was removed, its jumps became less spectacular. Finally, with the removal of its last leg, the flea remained motionless. Time after time the command failed to get the usual response.

The professor decided that at last he could publish his findings. He set pen to paper and described in meticulous detail the experiments executed over the preceding months. His conclusion was one intended to startle the scientific world: *When the legs of a flea are removed, the flea can no longer hear.*

Claude Bishop, the dean of Canadian science editors, told a similar story. A science teacher set up a simple experiment to show her class the danger of alcohol. She set up two glasses, one containing water, the other containing gin. Into each she dropped a worm. The worm in the water swam merrily around. The worm in the gin quickly died. "What does this experiment prove?" she asked. A student from the back row piped up: "It proves that if you drink gin you won't have worms."

NOTING STRENGTHS AND LIMITATIONS

The discussion is a place to note substantial strengths and limitations of research being reported. Some authors feel awkward about including such content. However, doing so can aid readers, and it can help show editors and referees (peer reviewers) that your work is publishable.

Some authors consider it immodest to note strengths of their work—for example, superior experimental techniques, large sample size, or long follow-up. However, such information can aid readers in determining how definitive the findings are. It also can help persuade peer reviewers and editors that your work deserves publication.

What if research had significant limitations—such as difficulties with a technique, a relatively small sample size, or relatively short follow-up? Some authors might try to hide such limitations. However, doing so runs counter to the openness that should characterize science. And astute reviewers, editors, or readers might well notice the limitations—and assume, either to themselves

or in writing, that you were too naïve to notice them. It is better, therefore, to identify substantial limitations yourself. In doing so, you may be able to discuss what impact, if any, the limitations are likely to have on the conclusions that can be drawn.

Not every discussion needs to discuss strengths or limitations of the research. However, if research has strengths or limitations major enough to be worthy of note, consider addressing them in the discussion.

SIGNIFICANCE OF THE PAPER

Too often, the *significance* of the results is not discussed or not discussed adequately. If the reader of the paper finds himself or herself asking "So what?" after reading the discussion, the chances are that the author became so engrossed with the trees (the data) that he or she didn't really notice how much sunshine had appeared in the forest.

The discussion should end with a short summary or conclusion regarding the significance of the work. (In some journals, papers include a separate conclusion section.) We like the way Anderson and Thistle (1947) said it: "Finally, good writing, like good music, has a fitting climax. Many a paper loses much of its effect because the clear stream of the discussion ends in a swampy delta." Or, in the words of T.S. Eliot, many scientific papers end "Not with a bang but a whimper."

DEFINING SCIENTIFIC TRUTH

In showing the relationships among observed facts, you do not need to reach cosmic conclusions. Seldom will you be able to illuminate the whole truth; more often, the best you can do is shine a spotlight on one area of the truth. Your one area of truth can be illuminated by your data; if you extrapolate to a bigger picture than that shown by your data, you may appear foolish to the point that even your data-supported conclusions are cast into doubt.

One of the more meaningful thoughts in poetry was expressed by Sir Richard Burton in *The Kasidah:*

> All Faith is false, all Faith is true;
> Truth is the shattered mirror strown
> In myriad bits; while each believes
> His little bit the whole to own.

So exhibit your little piece of the mirror, or shine a spotlight on one area of the truth. The "whole truth" is a subject best left to the ignoramuses, who loudly proclaim its discovery every day.

When you describe the meaning of your little bit of truth, do it simply. The simplest statements evoke the most wisdom; verbose language and fancy technical words are used to convey shallow thought.