AMERICAN MEDICAL WRITERS ASSOCIATION

AMWA JOURNAL

JUNE 1989

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The American Medical Writers Association (AMWA) *Journal* is the official Association journal and is published four times a year by the American Medical Writers Association, 9650 Rockville Pike, Bethesda, MD 20814. Telephone: (301) 493-0003.

The opinions expressed by authors contributing to this journal do not necessarily reflect the opinions of the American Medical Writers Association or the institutions with which the authors are affiliated. The Association accepts no responsibility for the opinions expressed by contributors to the journal.

Editorial Material: Manuscripts and correspondence should be sent to the Editor-in-Chief, Ronald J. Sanchez, American Medical Writers Association, 9650 Rockville Pike, Bethesda, MD 20814.

Book Reviews: Books for review and correspondence concerning manuscripts or reviews should be sent directly to the Book Review Editor, Lila N. Schwartz, 1322 Shattuck Ave., Apt. 201, Berkeley, CA 94709.

Dear Edie: Correspondence should be sent directly to Edith Schwager, 4404 Sherwood Road, Philadelphia, PA 19131.

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AMERICAN MEDICAL WRITERS ASSOCIATION JOURNAL

June 1989, Vol. 4, No. 2

ISSN 0090-046X

RESEARCH:

The Origins of the Scientific Paper: The IMRAD Format

The sameness of a manuscript's organization provides reliability

Robert A. Day

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The greatest invention of the nineteenth century was the invention of the method of invention.

—A.N. Whitehead

A scientific experiment has not been completed until the results have been published. If we accept that statement as true, we then can appreciate the overwhelming correlation that exists between scientific research and scientific writing. We can see that one is the reflection of the other. Therefore, by studying the literature of science, we can learn something about the history of science. And, although comparatively little has been written on the subject, we can learn something about the history of scientific writing.

When we examine modern scientific papers, we see a certain sameness about them. That sameness derives from the fact—and it is a fact—that almost all research papers in the sciences are organized in the same way. That organization has come to be known as IMRAD, the acronym standing for Introduction, Methods, Results and Discussion. Why is this so? When did the IMRAD format develop?

The Early History

It is tempting to say it started with Hippocrates some 24 centuries ago. After all, it is Hippocrates who is credited with the "discovery" of the scientific method. And perhaps it did *start* then. However, I contend that the modern scientific paper, especially in our field of biomedicine, was born one century ago, not 24, and that it has come into widespread use only during the past 50 years.

Hippocrates' scientific method (usually stated as: identify a problem, gather relevant data, formulate a hypothesis from these data, and then empirically test the hypothesis) was fine as far as it went. But it lacked (or at least did not overtly state) what we now recognize as the cornerstone of the scientific method: the *reproducibility of results*. The reproducibility principle did not become established in biomedicine until the 19th Century.

Prior to the 19th Century, scientists and scholars communicated with each other orally, by letter and, after the invention of the printing press in A.D. 1455, by books. The first journals were established in 1665. The early journals were of course "letters" journals (some of which still exist). The style of writing was descriptive, usually chronological. ("First I did this, and then I did that," etc.)

The Real Beginning

Not until the latter half of the 19th Century did the style of scientific papers begin to change. The change

in style resulted primarily from the work of Robert Koch and Louis Pasteur. The famous "Koch's Postulates" and Pasteur's development of germ-free methods gave final confirmation to the germ theory of disease while at the same time administering the final *coup de grace* to the old theory of "spontaneous generation."

Until the development of the germ theory of disease, the practice of medicine could hardly be called a science. The practitioners of medicine were powerless to prevent or treat the plagues and other infectious diseases that killed by the millions. Once the germ theory was accepted, the practice of medicine did indeed become a science and the results have truly been spectacular.

One can argue, and I do, that Pasteur's greatest contribution was *his* ability to argue. For Pasteur, it was not enough to prove the germ theory to his own satisfaction. Pasteur was hounded by numerous, and important, adversaries, most of them fanatic proponents of the theory of spontaneous generation. Pasteur courageously, in his books and other publications as well as in personal and public confrontations, argued effectively and persuasively in support of his ideas.

Particularly, what Pasteur did was to describe his experiments in such exquisite detail that any reasonable person could repeat them and get the same dramatic results. And thus did Pasteur essentially demolish the opposition. And thus did he espouse the power of the principle we now call *reproducibility of results*. And thus, by establishing "methods" sections in his publications, he established the basics of the modern IMRAD paper.

Pasteur and IMRAD

In his classic *Etudes sur la Biere*, Pasteur's use of the IMRAD style resonates throughout the book. Each section of the book describes a particular "study," and these sections read almost like a collection of journal articles. I will quote a few sentences from one of Pasteur's most famous studies. (I quote from the English translation edited by Frank Faulkner and D. Constable Robb and published under the title *Studies on Fermentation* by Macmillan & Co. in 1879.)

The "Introduction" covers several pages in which Pasteur outlines the "vital energy" theory of Fremy. The last sentence (p. 54) of this Introduction states Pasteur's purpose in no uncertain terms:

> *We at once resolved to demolish M. Fremy's theory, by a decisive experiment on the juice of grapes.*

After this ringing statement of purpose, Pasteur immediately launched into a detailed description of the methods he used in this experiment.

> *We prepared forty flasks, capable of holding from 250 c.c. to 300 c.c. [from 9 to 11 fl. oz.] and shaped as represented in Fig. 8. These we filled with filtered must, which was perfectly bright, and which, like all acid liquids, would remain sound, after having been boiled for a few seconds, although the ends of the long curved necks of the flasks containing the must might remain constantly open for months or years.*

After describing how the 40 flasks were divided into four series of 10 flasks each and variously treated, Pasteur is then ready to present his results, in good IMRAD form. His first sentence (p. 56) makes this transition absolutely clear:

> *The following are the results presented by our four series of comparative experiments in the different cases.*

When Pasteur completes his Results (of course he doesn't use these headings, perhaps not yet realizing that he invented them), he then begins the Discussion. Again, his polemical style makes this transition (p. 57) abundantly clear:

> *These experiments cannot leave the least doubt on our minds: That must, if boiled, will never ferment when in contact with air that has been freed from the germs which exist in it in a state of suspension.*

'Until the development of the germ theory of disease, the practice of medicine could hardly be called a science. The practitioners of medicine were powerless to... treat the plagues and other infectious diseases...'

To again show that he was not a student of Dale Carnegie, Pasteur stated his central conclusion:

> *"Thus, the hypothesis of MM. Trecul and Fremy, according to which albuminous substances transform themselves into grains of yeast by the action of a peculiar vital force, is annihilated."*

IMRAD Comes of Age

In the 50 years or so following the work of Pasteur, many journal papers began to look "modern." The papers of Paul Ehrlich (Salvarsan) in the early 1900s, those of Alexander Fleming (lysozyme, penicillin) in the 1920s, and those of Gerhard Domagh (sulfa drugs) in the 1930s are reasonably good examples of "modern" papers. Insofar as the papers in the first half of this century were not "modern," the organization tended to be loose and the language excessively wordy.

After World War II, science became big business. The wonder drug penicillin (although "discovered" a decade earlier) was developed during the War, and the later 1940s and 1950s saw the development of strep-

tomycin, the tetracyclines and many other "wonders." It was no surprise that the federal government began contributing massive financial support to scientists producing these wonders.

This positive reason for supporting science was soon followed by a negative reason. In 1957, the Russians flew Sputnik around our globe. Thus, in fear of getting behind, our Senators and Representatives eagerly appropriated still more money for science.

Money meant research, and research meant papers. And our journals were virtually overwhelmed by manuscripts pouring out of our research laboratories.

What could be done in this crisis atmosphere? We look back now, and what was done makes obvious sense. The editors of the journals, themselves and working through their organizations, began insisting on tightly written manuscripts in the IMRAD format.

Eventually, in 1972, the IMRAD format became "standard" with the publication of the *American National Standard for the preparation of scientific papers for written or oral presentation* (ANSI Z39.16-1972). Some 45 organizations approved this standard, including the American Chemical Society, American Institute of Physics, American Library Association, Association of American Publishers, Council of Biology Editors, Medical Library Association and National Academy of Sciences.

In the 25 years since the adoption of this ANSI standard, the IMRAD format not only has been adopted throughout the sciences but also has spread to the social sciences and even to some professional journals in the arts and humanities.

In the early days of IMRAD, some editors and many writers argued that the IMRAD format was too rigid and that this rigidity would inhibit the personal "style" of authors. Later, many editors (if not writers) came to believe the great accomplishment of IMRAD devolved precisely from its rigidity. Scientific papers are now logically and rigidly organized in a format readily recognizable and understandable by their writers, reviewers, editors and readers.

Medical writing is still not easy. And we all know that medical editing is still not easy. However, thanks to Pasteur and IMRAD, we are all following the same roadmap and we usually arrive at or close to the destination: the logically organized, well-written scientific paper. □