ACCESSING “THE SCIENTIFIC LITERATURE”

Robert V. Blystone, Ph. D.
Professor of Biology
Trinity University

To many undergraduate students, the term “The Scientific Literature” represents a vague, immutable collection of complicated writing. It is important for these students to recognize that “The Scientific Literature” is a dynamic collection of information that is constantly changing and subject to considerable interpretation. A series of four exercises have been developed that allow students to gain an understanding of what is meant by “The Scientific Literature”. These exercises can be added as enrichment to any number of undergraduate science courses, although here they are cast with a biological perspective.

Assignment One:

A major, short, original source article.
A good starting point in demythologizing the scientific literature is with James Watson and Francis Crick’s first DNA paper. The reference is Nature 171: 737-738 (1953). Begin by asking the students: “Who are the most important figures in modern biology?” Mendel, Darwin, and Watson & Crick usually head the list. Charles Darwin expressed his notable thoughts in the Origin of Species in 1859; Gregor Mendel in his publication “Versuche über pflanzenhybriden” in Verhandlungen des Naturforschenden Vereins Brünn 4: 3 in 1865; and, Watson & Crick in their Nature article. Of the three major biology works cited above, the Nature article is the most accessible as a pedagogical tool.

Although most students have read the Declaration of Independence as a school assignment in an American History class, few Biology students have ever been instructed to read the original work of the four major figures listed above.

Ask the students to characterize what they think they will find in the original Watson & Crick paper. Questions that could be posed would include the following: 1) How long is the paper; 2) How many figures and tables; 3) How extensive are the literature citations; and 4) What are the major thoughts expressed in the paper? Generally, students expect the research paper to be more than ten pages long with perhaps a dozen or so figures, accompanied by 40 or 50 references, and possibly laced with information about introns and exons. These impressions, although regrettable, are understandable. Most Biology students have only encountered textbook representations of their subject. They have not had the opportunity to experience original source material.

Send the students to the library stacks to seek the nearly 40 year old article. Nestled among rows of the neatly bound Nature series is the sought after Volume 171. Resist the temptation of handing out a photocopy of the article. Fresh stark photocopies just don’t have the texture, the color, or the smell of 40 year old, acid containing paper. This trip may well be a student’s first act of reading original source material in science. Request the students do something else
on this library trip: Go and look at Life magazine of the same date as the Watson & Crick paper. This act helps place the paper into a historical context. It is important that the students experience the world of these scientists at the time they were recording their thoughts.

At the next class session, students need to compare their findings with their previous impressions. By analogy to the scientific method, will a student modify his/her hypothesis of what the seminal DNA paper was like? Most students are surprised that the paper was only one page long. These students also agree that the subject material was very simple and that their textbook accounting is far more complex. What really amazes students is the realization that Watson & Crick did little laboratory research in support of the paper. At this point, I introduce students to the work of Thomas S. Kuhn, author of The Structure of Scientific Revolutions, University of Chicago Press, 1972. The concept of paradigmatic shift is nicely represented by the Watson & Crick paper. For students who seek term paper subjects in modern history, reading concepts of the molecular basis of heredity three years before Watson & Crick's paper and three years after is quite illustrative of a paradigmatic shift. You might want to direct students to Watson’s & Crick's second Nature paper, published five weeks after the first (Nature 171: 964-67 (1953)). The rush to be first into press is quite evident in these two papers. A fact that Watson recounts in his book The Double Helix, Athenum Press, 1968.

**Assignment Two:**

**Types of papers and accuracy**

This first assignment has taken students into original source material and attempts to put that material into context. The second step is to show students how to measure the importance of a paper. *Science Citation Index* (Institute for Scientific Information, Philadelphia) offers a path to this objective. The structure and function of *Science Citation Index* as a reference guide should be explained to the students. The following question is posed: "Does the number of times a paper is cited in other scientific works bear a relationship to the importance of the paper?" Most students intuitively accept that important papers are cited often. Students are given the assignment to see how often the Watson & Crick paper is cited each year during 1985-1989 as recorded in *Science Citation Index*. They are also asked to review the citation rate for the same period of the paper by O. H. Lowry, N. J. Rosebrough, A. L. Faw, and A. J. Randall, in the *Journal of Biological Chemistry* 193: 265 (1951).

Of course, most students have never heard of the Lowry et al. paper nor do they know that this work is easily the most cited science paper of all time. The paper is typically cited more than 5,000 times per year. Watson & Crick's two papers are referred to about a 100 times or so per year in the *Science Citation Index*. Watson & Crick have a Nobel prize but who has heard of Lowry; certainly many scientists. At this point, the different styles and types of scientific papers can be introduced. Categories could include the following:

a) technique and methodology,
b) concept and theoretical,
c) review,
d) abstracts, and
e) the "standard" research paper.

Lowry et al. would serve as an example of the first category and Watson & Crick would fit into the second category best. Students should recognize that scientific findings are generally reported in small segments called the "scientific paper." Darwin's *Origin of Species* is atypical as a means of introducing bold new ideas.

The contrast between Lowry et al.'s and Watson & Crick's citation rate indicates that a 100 to 1 difference does not necessarily translate into quality or differences in importance. A question to be considered is: What was the influence of a methodology that allowed a quick, reliable, and inexpensive determination of
protein concentration to Watson's & Crick's thinking two years later? The relatedness of scientific literature can be established by this type of contrast.

Another feature of the scientific literature can be illustrated by the Lowry et al. paper. Students may have noted how many incorrect citations of that paper appeared each year in the Science Citation Index. One percent or more of this paper's citations are incorrect. What does this observation have to say about other possible errors in research papers? How does an incorrect citation of such a well-known paper get through the review process? At this point students are presented with their third assignment.

Assignment Three:

The citation rate of the "standard" paper
Attention is now directed to the "standard" research paper. As I keep up with the literature, I look for papers that are about six pages in length, with about twenty references, and in the "standard" form; i.e., introduction, methods, results, and discussion. Reprints are acquired and filed by year. Each student is given a paper that is ten years from the date of publication. Each paper assigned has been cited at least once during the ten year interval since its publication.

The third assignment involves four students and strict deadlines. Each student receives a random reprint and is designated as the "author" of the reprint. The reprint now serves as an original article submission. The "author" must now submit the article to another student who serves as the "editor" of a journal. The student "editor" agrees to take the paper. Then the editor sends copies of the paper to two other classmates who agree to serve as "reviewers". A great deal of cooperation between the students is necessary, an action that mirrors the real scientific community.

The responsibilities of the reviewer include the following: 1) expression of the sense of the paper, 2) determination of the correctness and suitability of the citations and references, 3) placement of the contribution of the paper to the body of knowledge, and 4) recommendation of the suitability of the paper for publication. The student reviewer has a distinct advantage over "real" reviewers. There are ten years of literature since publication of the assigned paper upon which to base judgements. The editor has the following tasks to perform: 1) assignment of the paper to reviewers, 2) keeping the reviewers on schedule, 3) evaluating the reviewers comments, 4) rejecting or accepting the paper, and 5) preparing a one page letter to the author expressing the publication decision. The "author's" actions include the following: 1) selection of the editor, 2) collection of the ten year citation rate data for the paper, and 3) the submission of all documentation for instructor evaluation.

This involved exercise has each student serving as an author, editor, and a reviewer of two papers. The interconnected nature of scientific publication is revealed, as well as its process.

Teamwork, deadlines, and decisions are all intermingled. This assignment typically requires one month to perform. To conclude this section I inform the students that half of all scientific papers published are never cited. The question is often asked if that means half the papers published are irrelevant. The discussion can be surprising. In one class a student remarked that Van Gogh only sold two paintings while he was alive. Her question was: "Should he not have painted?" I finish the discussion by asking the class: "If the year was 1875 and Mendel's 1865 paper was part of our class exercise, what would we conclude?"

Assignment Four:

Finding a current worthwhile paper
The fourth assignment is based on the current literature. Each student is asked to find a research paper published within the last twelve months that represents a significant contribution to science. The identified paper is accompanied by a one
page justification of the selection. I have the class discuss among themselves the attributes of a good paper. Concluding the assignment, I challenge each member of the class to write me in ten years and indicate how good his or her choice was.

Conclusion and Summary

These exercises can serve as a very viable alternative to a term paper. The students learn to find original source material, how to use a major reference tool, follow the course of scientific paper review, and try to pick out a significant recent paper. Students' bibliographic skills are enhanced as they learn to access "The Scientific Literature."

LITERATURE CITED


Editor's Note: For a very different reading of Watson and Crick (namely, as a fairy tale) that is likely to excite or enrage your students, consult Alan G. Gross's "The Tale of DNA" in his (1990) book entitled The Rhetoric of Science. Cambridge, Massachusetts: Harvard University Press.

Teaching Students about Science -- A Modest Proposal

Annette Baich, Southern Illinois University, Edwardsville

Many, if not most students in high school take biology as their one, and possibly only, course in natural science. Yet the understanding of this complex science in the way in which it is usually taught presents the most difficulty for beginning students for both theoretical and practical reasons. The unifying theory which explains observations about plants and animals is evolution. This theory is one in which at least a third of the teachers do not themselves believe and do not teach. In addition, many school districts frown on teachers who attempt to teach this theory. These are practical difficulties. The theoretical difficulty lies in evolution itself, which can best be understood as a . . . "chancy result of a long string of unpredictable antecedents, rather than as a necessary outcome of nature's laws" (Gould, 1991). Thus, evolutionary theory is not predictive. Prediction of the results of future experiments is the strongest support for an hypothesis. In traditional biology, students are presented with masses of empirical information, but the only theory available to organize the data cannot predict future events. It becomes clear that teaching students to understand that science is a problem-solving procedure that depends upon a theoretical understanding of the subject is not readily done in the framework of classical biology.

Molecular biology suffers neither the practical or theoretical problems listed above. It has a strong theoretical foundation in basic atomic theory, and the important subject of evolution may be taught as a natural consequence of molecular events. There is yet no organized religious movement to obstruct the teaching of molecular biology. My modest proposal is that in the future, high school teachers of biology should be educated most thoroughly in molecular biology, rather than the more traditional botany and zoology. By concentrating on the teaching of molecular biology, future teachers of biology can demonstrate easily the basic principles of scientific thought, as well as the unbroken thread that unites all of the natural sciences, including biology.