Writing About Biology: How Rhetorical Choices Can Influence the Impact of a Scientific Paper

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ABSTRACT: A comparison of the landmark papers by Watson and Crick (1953) and Avery *et al*. (1944) shows how different rhetorical choices can influence the impact of a scientific paper. The paper by Watson and Crick revolutionized biology and remains a model of scientific rhetoric. In contrast, the paper by Avery *et al*. reports equally important findings, but its impact was greatly diminished because of rhetorical choices made by its authors. Together, these papers provide an interesting and valuable case study for teaching students the importance of rhetoric and writing in science.

KEYWORDS: DNA, writing, rhetoric, Watson, Crick, Avery

In 1953 James Watson and Francis Crick forever changed our understanding of biology by publishing their virtuoso paper entitled "Molecular structure of nucleic acids: a structure for deoxyribose nucleic acid" (Watson and Crick 1953). That paper, which described the double-helix structure of DNA, won Watson and Crick a Nobel Prize, made them famous worldwide, and gave birth to molecular biology (Stent 1980).

Watson and Crick's work was remarkable, as was the style in which it was reported. Unlike virtually all other research reports of its time, the paper by Watson and Crick was an accessible and entertaining paper that -- in the tradition of Galileo Galilee and Charles Darwin -- could be read and understood by educated laypeople. It was a model of scientific rhetoric (Halloran 1984) and its writing style was revolutionary; the paper reads like no other research report in modern science (e.g., see Moore 1994 and references therein). What made Watson and Crick's paper so important? Stated another way, was the dramatic impact of Watson and Crick's paper due to its "writing style," or was its effect solely due to its "content"? To answer this question, I've compared the paper by Watson and Crick with another seminal but not nearly so famous paper in molecular biology entitled "Studies on the chemical nature of the substance inducing transformation of pneumococcal types" by Oswald Avery, Colin MacLeod, and Maclyn McCarty (Avery *et al*. 1944). Although analyses of the paper by Watson and Crick have been presented elsewhere (e.g., Halloran 1984; Moore 1994), no such analysis has been made of the paper by Avery *et al*., despite the fact that the research reported in that paper has been referred to by Nobel laureate Peter Medawar as "the most interesting and portentous biological experiment of the twentieth century," and by fellow Nobel laureate Joshua Lederberg as "the pivotal discovery of twentieth-century biology" (Lederberg 1994). Indeed, the work of Avery *et al*. began the modern era of genetics (Lederberg 1994). Despite its importance, however, the work of Avery *et al*. did not win a Nobel Prize and was not initially appreciated outside of a relatively small group of researchers. Even today, Avery *et al*. -- unlike Watson and Crick -- are seldom mentioned in introductory biology textbooks. Why did the paper by Watson and Crick receive such acclaim and have such widespread impact, while that of Avery *et al*. -- the paper on which the work of Watson and Crick was based – was unappreciated or ignored (McCarty 1985)? What can we learn from these two papers about teaching students the importance of effective writing in biology?

The Work of Avery, MacLeod, and McCarty

The paper by Avery *et al*. (1944) was the first published report that DNA is the hereditary material. Avery *et al*. reported a series of thorough, meticulous, and convincing studies of *Streptococcus pneumoniae*, a bacterium that is often abundant in people suffering from pneumonia. Here's what Avery *et al*. reported:

> Bacteria have inheritable features that are associated with virulence. When DNA from

a virulent strain of the bacterium was mixed with cells of a less virulent strain, some (~1 x 10^{-4}) of the bacteria developed characteristics of the virulent strain. These newly acquired traits were passed to all offspring of the changed, or "transformed," bacteria. That is, the hereditary material of dead bacteria could modify the hereditary material of a living organism, indicating that the hereditary material could move from one clone to another in a cell-free extract.

The addition of enzymes that degrade proteins and RNA (the other type of nucleic acid) but not DNA did not affect the ability of the "transforming substance" to transform cells. Thus, the substance causing the transformation was neither protein nor RNA. This was a critical experiment and conclusion, for most biologists at the time believed that protein was the hereditary material and that DNA lacked the specificity to serve as hereditary material.

The addition of an enzyme that destroyed DNA resulted in no transformation. This, too, was consistent with the conclusion by Avery *et al*. that the substance responsible for transforming the bacteria was "a deoxyribose-containing nucleic acid" -- that is, DNA.

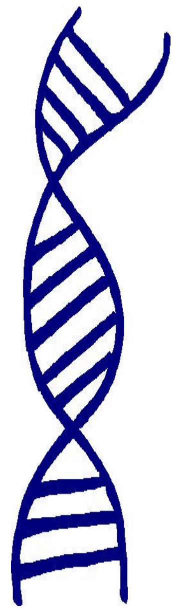
Avery *et al*. had isolated genes in pure chemical form, and were the first scientists to show that genes are made of DNA. By implication, the work of Avery *et al*. also suggested that the genes of other organisms (e.g., *Drosophila*, humans) were made of DNA. These were landmark discoveries.

The Impact of the Work of Avery et al.

The work of Avery *et al*. was well-known (but not well-appreciated; see below), overturned a widespread assumption about genetics, and laid the foundation for the subsequent work of Watson, Crick, and many others (Lederberg 1994). The experiments reported by Avery *et al*. were technically thorough and their conclusions were well founded. Nevertheless, the paper by Avery et al. was neither widely accepted nor appreciated by most people in the scientific community (e.g., see Freifelder and Malacinski 1993; Darnell, Lodish, and Baltimore 1990) and did not have an immediate transforming effect on biology or genetics. The conclusions of Avery *et al*. were referred to as "premature," and many biologists (e.g., Alfred Hershey) continued to express reservations that DNA was the hereditary material.

The Rhetorical Failures of Avery et al.

Why didn't the work of Avery et al. receive, as Francis Crick (Crick 1974) later claimed, "a very fair hearing," while that of Watson and Crick had a revolutionizing impact on science? A major reason why the work of Avery *et al*. failed to have an immediate and profound impact was the rhetorical choices made by the authors. The consequences of these rhetorical choices are dramatic and obvious (Halloran 1984) when the work of Avery *et al*. (1944) is compared with that of Watson and Crick (1953).



Conciseness. Watson and Crick were extremely concise; their paper is only about 900 words long. Avery *et al*. were verbose; their paper is about 7,500 words long. Many great scientists have used concise writing to increase the impact of their work. For example, Kornberg described the synthesis of DNA with only about 430 words, Lipman described coenzyme A with only about 250 words and one table, and Cournand and Ranges described the first catheterization of a human heart with only about 950 words (Moore 1994; Schwager 1991). For comparison, the USDA's directive for pricing cabbage contains 15,629 words (Moore 1992).

Level of detail. Watson and Crick presented only a sketch of their model, with a "minimum of hedging" and "in simple terms, unmarred by any trace of algebra" (Crick 1974). Avery *et al*. described in painstaking detail how they arrived at their conclusions. Whereas the paper by Watson and Crick was accessible and relatively easy to read, even for non-experts, the paper by Avery *et al*. is dense and difficult to read, even for an expert.

Confidence of authors. Watson and Crick were glibly confident of their conclusions; according to Crick (Crick 1974), their presentation "leaves little doubt" that Watson and Crick "thought they had a good idea." Avery *et al*. seemed hesitant to make conclusions, and Avery himself had "nagging doubts" about whether they were right (McCarty 1985). Whereas Watson and Crick exuded confidence, Avery *et al*. were "reserved" and "low key" (McCarty 1985). The glib style of Watson and Crick annoyed and even offended many scientists. Erwin Chargaff, whose findings Watson and Crick used when formulating their model, became an outspoken critic of Watson and Crick (Chargaff 1968, 1974). Another critic commented, "That in our day such pygmies throw such giant shadows only shows how late in the day it has become" (Judson 1978).

Forcefulness of presentation. Watson and Crick stated their thesis in their paper's opening sentence ("We wish to suggest a structure for the salt of deoxyribose nucleic acid [D.N.A.]."). Avery *et al*.

did not state their thesis in their opening paragraph, and did not mention DNA until about halfway through their paper.

Importance of work. Watson and Crick proclaimed their work as important in their paper's second sentence ("This structure has novel features which are of considerable biological interest."). Conversely, Avery *et al*. made no claims about the importance of their work; instead, they described their work as being merely a "more detailed analysis" of an already well-known process.

Persuasiveness. Watson and Crick lured their readers with first-person statements that emphasized their activities (e.g., "We wish to put forward..." "We wish to suggest...") and, by implication, their rejection of the supposition that data can speak for themselves. Avery *et al*. used dull, agentless writing and passive voice (e.g., "It may be shown that..." "It must be decided whether...") to imply that their conclusions were produced without human intervention. Avery *et al*. even referred to themselves abstractly as "the writers." Interestingly, one of Watson and Crick's rare uses of passive voice was in reference to their critic, Erwin Chargaff (see above). Rather than cite Chargaff by name, Watson and Crick wrote "It has been found experimentally that..." thereby making Chargaff's contribution anonymous (Moore 1994).

Teaching Students the Importance of Writing and Rhetoric in Science

Scientists must do more than present data and facts; rather, scientists must persuade others by making effective arguments. The papers by Avery *et al*. and Watson and Crick provide excellent case studies for how the rhetorical choices used to construct those arguments affect the impact of a science paper. Together, these papers provide an excellent foundation for teaching students the importance of writing in biology. When combined with the stories underlying the discoveries (McCarty 1985; Watson 1980), these papers can also introduce students to how science is often done.

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