Students and Professionals Writing Biology: Disciplinary Work and Apprentice Storytellers

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I. Introduction

The character of formal scientific writing has been well defined by various rhetoricians and sociologists of science. In most cases, published professional work follows the general scientific format of abstract, introduction, methods and materials, results, and discussion, Much has been written about the ways in which this structure effaces the role of the experimenter/writer and instead presents the object studied (nature) as operating autonomously; results are made to appear to be merely the quantified revelations of this operation.[1] At the same time, much work has been done on student writing in the sciences, Composition and writing across the curriculum specialists have established that various "write-to-lead strategies can be incorporated into the science classroom and have studied pedagogical approaches to teaching scientific writing.[2] What has not been taken into consideration in nearly the same detail are the rhetorical differences which set student writing apart from professional work in the sciences. Such a comparison would offer rehtoricians a vision of the underlying framework generally concealed beneath the airtight smoothness of professional discourse.

For this project I have studied the differences and similarities between student and professional writing in the biological sciences. Ultimately, I found that the student writer is granted apprentice status in the discipline of biology when s/he comes to understand two central things: that the format of the scientific paper has at stake the separation of the "natural" from the human; that the "human" function of interpretation and argument is dependent for its legitimacy on the narrative presentation of a "natural" process, I use "natural" in quotation marks in order to emphasize that the subject matter of a narrative is no more removed from the human who writes than that of any other rhetorical form. The function of formal writing in the discipline of biology is to

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establish the illusion of "natural" time through an abstract "story" which validates the scientific claim by (rhetorically if not actually) preceding it. If this process of emplotment is precisely the task of writing in the discipline, however, that fact is rarely explicitly articulated. Instead, students are given advice for writing "lab reports" that not only contradicts itself but that helps to mystify how legitimate knowledge is actually structured in the discipline. As Ball et al. say of academic work generally, the "constitutive knowledge of the discipline.. .is naturalized and kept hidden by institutional representations of disciplinary work" (356). I shall explore this premise by contrasting the stylistic norms of professional and student writing in biology; my goal is to foreground the gap between what the institution nukes explicit for students and what it keeps to itself.

II. Methodology

The research examined here is part of a larger study I am conducting on the gaps between the discipline-specific expectations of faculty and the explicit articulation of those expectations for student writers. I study one academic department per semeester, accumulate data (faculty interviews, syllabi, assignments, comments on student papers, publications; student interviews, papers), and shape that information into a report that I present to the appropriate department. What has been particularly useful for me in this has been access to faculty grades and comments on student writing; evaluation reveals a great deal-generally in implicit ways-about how certain shapes of writing and knowing are valued above others in the disciplines and how that prioritization is communicated (or not) to students.

Data for this particular study was gathered between the spring semester of 1992 and tie spring semester of 1994. I interviewed all biology faculty members at my institution (a small liberal arts college in Pennsylvania about the teaching of writing and the structure of scientific writing; I collected and studied graded student writing from several sections of General Biology as well as from assorted upper-level courses; I examined all the articles published in six central professional journals in 1993-4; I solicited other data such as syllabi, assignments, and style guides. This research has been admittedly unscientific, owing as it is to understandable faculty and student hesitancy; however, the repeating themes have been striking, particularly in terms of grading criteria, articulation of those criteria, and structures of writing. For example, students almost universally claim that writing in their biology courses is about "facts"; conversely, their paper grades show that they are regularly penalized for not organizing and selecting what will count as "factual." In interviews, faculty articulate a desire for greater "clarity" and "brevity" in student writing; their comments on students' papers reveal a greater expectation for narrative emplotment.

Ill. Discussion of Findings:

A. The Style Guide

The "Style Guide" given to all students in General Biology provides a clear example of the contradictions and mystifications embedded in "institutional representations of disciplinary work." The guide takes students through the traditional sections of the research paper (abstract, introduction, materials and methods, results, discussion, tables, works cited) and then offers them the additional stylistic advice to "be brief' and to "be precise," to "use exactly the right term for what you mean, even if this means you must repeat the term several times in a paragraph." This expectation for representational "truth" in scientific writing is contrasted explicitly with what are described as the more aesthetic but less mimetic qualities of writing in the non-scientific disciplines: "You may have been taught to vary your expressions and use synonyms, but in scientific writing precision has a higher priority." In other words, "precision" is a function of fewer total words, fewer "synonyms"; writing "precisely" (and scientifically) is a process of perceiving the "thing" for what it is and naming it correctly. Significantly, exactly half of the fourteen lines of advice about style explain the format of the scientific name. The message is clear: nature can be reflected in the mirror of scientific writing if that "nature" is precisely encoded into its corresponding scientific names. Writing within the social sciences or arts and humanities, in contrast, is thus implicitly defined as an enterprise not primarily concerned with representation -- with correspondence between word and thing-but rather with an enclosed and perhaps reflexive multiplication of verbiage.[3] Unsurprisingly, then, the style of scientific writing is also defined for the student as involving a great deal of "cutting." Fewer words meangreater correspondence to the world; more words imply an imbalance. Brevity ("Be brief. Cut out needless phrases") is the soul, not of "wit," but of truth.

Alongside these directives to "be brief' and "precise" is the advice to "stick to the point." This is an interesting complication. If nature is to be mirrored through a precise one-to-one translation into scientific names, then there is no particular "point" involved; that one should have a "point" implies a certain agenda or pattern of individual choices, a certain amount of literary shaping, a goal having to do with audience reception. The necessity of "sticking to a point" also implies a sidelong glance toward the multiplicity of semiotic - and natural? - possibilities that await the unsuspecting and unfocused writer. A "point" is necessary only in a world of dizzying abundance, a world opposed to being easily and permanently codified. This seeming contradiction between reporting and "making a point" is repeated elsewhere in the style guide. In the introduction, for example, students are told on one hand, that

> Contrary to what many people believe, scientific writing is not fundamentally different from other kinds of formal writing. A superbly-written scientific paper is logical, clear, and makes a cogent point. It is also readable, provocative, and even exciting.

In the next paragraph, on the other hand, students are told that "the major goal of a scientific paper...is to report descriptive or experimental observations." "Sticking to a point" and observing/reporting are thus presented as if they do not contradict each other as goals, and yet there is no clear explication of how they might interlock. Is scientific writing about mirroring the natural world, about making and defending a point, or about a subtle combination of both?

Ultimately, this contradiction (and its apparent invisibility to the writer of the style guide and the professors who assign it for classes) is lodged in the attempt to explain to students the formalities of scientific writing and the relationship of these formal constraints to the natural world. That there are formal constraints and that they derive not from nature but from human language/knowledge systems is self-evident and in some contexts easily admitted:

> . ..some conventions have evolved that most scientific writers follow. When you first try these you may feel confined and awkward, in somewhat the same way as in writing a first haiku or sonnet.

What is not so easily explained is how -- and how much -- these "conventions" change *from the beginning* the nature of the thing observed and reported. The writer of the style guide claims that it is "*because of* [the] priority" of description and experimental observation that "conventions have evolved" (my italics). The logic of this claim is odd: it is *because* the goal of scientific writing is pure representation that impure forms -- forms that replicate the imprecision of the arts and humanities -- have evolved, Somewhere in this explanation is a failure to acknowledge the complicated nature of "reporting"; in between the linguistic form and the material world is the shaping mind perceiving through language, and this is what is excluded from discussion--just as it is excluded from the formal written genre of the discipline.

B. The Structure of the Genre

I. "Methods and Materials" in Professional and Student Writing

The largest portion (roughly 70%) of almost all professional articles and student papers examined for this study is composed of the sections on methods and materials-the section whose purpose is to provide the objective base for all and any interpretative moves. This section removes the disinterested "reporting" and "observation" of the experiment from the more explicitly interested introduction and results/ discussion: the introduction must take up the relationship of the study in question to previous work as well as the guiding hypotheses of the current researcher; the discussion must "interpret" the results, an action that necessarily and obviously involves some human intervention. The successful materials and methods section, on the other hand, must exclude all reference to the shaping experimenter-as well as to the shaping and constructive writer.

The materials and methods section functions to place the experiment within the rhetorical framework of an idealized and seamless narrative. The extent to which this legitimating section is necessarily separated fiom human hands is evident in the ongoing use of passive constructions. In the case of the professional articles examined for this study, all methods and materials sections were written entirely in the passive voice, The general effect is that the "doer" of the experiment is rhetorically subordinated to the object-which Bazerman claims is "taken as given, independent of perception and knowing"(31)-and its transformation through time. Here, for example, is a representative passage from an article on the "direct monitoring of intracellular calcium ions in sea anemone tentacles" from *The Biological Bulletin:*

> For experiments involving fluo, whole animals were incubated in a 20-pM fluo-3 AM solution for 40 min at 23°C and then washed twice for 10 min each. Tentacles were excised, placed on glass coverslips, and secured with glass micropipettes (tip diameters of <1 mm) by applying gentle suction with microinjectors. (Mire-Thibodeaux and Watson 336)

This style of writing not only removes the human actor from the scene, portraying nature as almost alone, but it also reinforces this sense of impersonality by generalizing the events of the experiment, transforming them to an idealized narrative. No reference is made to the accidents, the unexplainable incidents, the awkward confusions that generally accompany scientific practice -- the events of "incoherence and uncertainty" that Pickering argues are "the hallmarks of experiment" (277).[4] Instead, experiences are generalized into one linear trajectory that is presented as if observable by any disinterested viewer capable enough to set events in motion.

What I refer to here as the generalized trajectory of the experimental narrative Gilbert and Mulkay articulate similarly as a series of abstract "rules"; the methods section of a scientific article, they argue, is constructed as if

> all the actions of researchers relevant to their results can be expressed as impersonal rules; as if the individual characteristics of researchers have no bearing on the production of results; as if the application of these rules to particular actions is unproblematic; and as if, therefore, the reproduction of equivalent observations can be easily obtained by any competent scientist through compliance with the rules.(52)

Gilbert and Mulkay go on to contrast this formal impersonality of scientific writing with scientists' informal and spoken admission of personal involvement in the formulation of results. The interviews that Gilbert and Mulkay have conducted reveal the extent to which these "rules" are dependent for their practical meaning on individual context, on "variable craft skills, intuitions, customary knowledge, social experience and technical equipment available to individual experimenters" (55). Similarly, Gooding works with what he calls the "technique" or "skill-ladenness" of observation.

If the methods section of professional writing obscures the personal and unique in order to produce the impersonal and general, however, student writing often blunders into revealing its own constructive hand; such blunders are instructive in providing a clear sense of what must be cut from a scientific paper in order to preserve the core section of disinterested observation which grounds all interpretation. The most common type of awkwardness is caused by students contorting their syntax in order to preserve the passive voice, as in these typical sentences from papers turned in to Introduction to Biology:

— When calculating the total number of species identified, fungi located in clumps were counted as a single entity.

— Using one empty mouse cage constructed a simplified version of an obstacle course.

In both cases, the students are attempting to remove themselves from the natural subject position and offer agency instead to the object studied (in the first case) or the experiment itself (in the second). Furthermore, although faculty interviewed for this study claimed that they encourage (some) students to avoid passive voice in order to circumvent such cases of convoluted syntax, the evidence shows that in fact it is only the students destined for lower than average grades whose editing comments push active voice; the best writers, the students judged to be doing "A" quality work, are never told to avoid the passive voice-which they almost always use.[5] The best work in the discipline is still presented passively, and those judged to be apprentice insiders are implicitly taught this fact. It is thus perhaps somewhat disingenuous to encourage students to resist a form that would ultimately help to legitimate them.[6]

More telling than these syntactical problems are slips in impersonality. A lapse in self confidence, for example, plunges the tone of a paper back toward personality, as in this case: "Algae types were identified to *the best of our abilities* and records kept on each tube" (emphasis added). The writers' expressed lack of faith in their own identification skills turns the paper toward self-reference and away from the object studied (algae). This type of self-reference, interestingly, is rarely commented upon by graders, and yet only the papers judged to be lower than average make these types of blunders. One paper turned in for a independent research project, for example, is filled with personal moments like these:

> Because of the lateness of the season, it was more difficult to collect fungi specimens with all of the leaves on the ground. We were lucky though and discovered a large amount of Polyporus sulfereus ("Chicken of the Woods," which we will refer to as 'chicken') growing in the front yard of Dickinson's president A. Lee Fritschler.

Clearly this paper does not replicate the tone of the *Biological Bulletin* because of its haunting sense of personal humor, its implicit reference to desperate and procrastinating college students picking leaves from the president's lawn. The personal anecdote intrudes on the generalized narrative. Significantly, the professor comments generally that "the paper...needs a little more work, to be gotten into proper journal article format." In addition to combining the introduction and abstract (which the professor comments on), this student has not managed to replicate the precise nature of professional scientific narrative, the "evidence" portion of the scientific article that upholds the ultimate interpretation. It is essential for purposes of validity that methods and results sections maintain what Barry Barnes has usefully termed "a cosmology firmly denying man (sic) any special significance"; it is this "cosmology" that accounts for the characteristically scientific "aversion to anthropocentrism and anthropomorphism" (45). "Man" returns onIy to the writing of those who are not quite conscious of the scientific requirement for non-reflexive evidence.

Nowhere in all the papers and professor comments examined for this study, however, did I see an explicit articulation of the problem of self-reference, Problems with syntax are corrected, and general comments about "appropriate format" are made, yet the problem of explicit textual shaping is not explicitly addressed. The problem of self-reference is apparently so central to the discipline that even reference to self-reference is avoided. What is articulated instead as the central problem in student writing-both in paper evaluations and in interviews-is the perennial lack of "clarity." Contorted passive syntax and tonal inappropriateness are subsumed within this general category that implies that only "concision" is at stake in report writing. As in the "Guide to Scientific Writing," the final answer is always that in spite of the "artificial" form of the lab report, in spite of the "point" one must ultimately make, scientific writing comes down to being "clear" and being "brief," establishing a one-to-one correspondence between words and nature, between narrative and experiment-as if naming things precisely will necessarily entail emplotment. In the case of the "chicken weed" paper discussed above, for example, although the final comment is that the paper is not yet in "proper journal article format," the margin notes written throughout the methods section draw constant attention to the issue of "wordiness." When the student writes that "after the spores had fallen out and had been collected, we had to then begin to prepare the agar plates," the professor writes, "Pretty wordy. Try to condense." When the student writes that there "is [was--sic] a grand total of 27 plates (just for chicken spores)," the professor writes, "Clear but still wordy. Try to condense." When the student comments that "the light/darkcontrastplates were a little tougher though," the professor responds with "Nice setup! Keep practicing condensing, though."The articulated editorial desire for greater brevity in these sections helps to disguise a problem that is even more specific and more central: the narrative flow is disrupted not only by "wordiness" but by tense shifts (to the present moment of writing) and other personal intrusions-suggestions of purpose, decision making, emotional responses, self reflection.

This issue of narrative flow is, I think, a central one. Myers has established that the form of the methods section in biological discourse is generally narrative and that the structure of this narrative is highly contingent on contextual variables such as audience, the relative power of the writer, the number of contending claims, the amount of unknown data, etc.[7] In terms of explicit function, the methods section purports to describe "what was done" and "what happened." Thus Gilbert and Mulkay's contention that methods sections are constructed "as if all the actions of researchers relevant to their results can be expressed as impersonal rules"' (52) is misleading to the extent that it does not take into account the implicit fact that a "rule," whether personal or not, is not necessarily a function of time but rather of space, or spatialization. In fact, genre theorists outside the field of the sociology of science have critiqued the discourses of the social sciences partly by contrasting them with the narrative structure of the natural sciences; writing in the social sciences is accused of "abstract objectivism," the relocation of the temporal and contextual onto the encyclopedic grid of space.[8] The task of the biological researcher when writing a methods section, conversely, is not so much to list abstract rules of operation as it is to tell the generalized story of what s/he did to certain materials to set a certain course of events in action. This story telling is clearly impersonalized and abstracted-s/he must tell the story of what s/he did without explicit reference to her own part in the drama--but it is not detemporalized.

Writing a clear and cogent methods section, then, is about "emplotment," a term commonly used to describe historical discourse and implying that coherence, meaning, and argument are constructed through the narration of selected "events."[9] Narrative emplotment is a form of discourse that easily masquerades as being "true" and without human intervention and purpose; as de Certeau puts it of historical writing, narrative "discourse takes on the color of the walls; it is 'neutral' ...instead of being the statement of 'causes' which might express a desire." *(The Writing of History* 68) This narrative "neutrality" is "established out of principle by a will to objectivity," a will that creates distance between the teller and the told, the voice of the present tense and the object that is safely and rhetorically in the past, by itself, inviolable. It is through this "will to objectivity" that "storytelling...renders believable what it says[;] in pretending to rewunt the real, it manufactures it." (*Heterologies* 4, 207)

The function of the methods section of a scientific paper, in this reading, is precisely to "render believable" the conclusions of the researcher, to construct a believable story. Scientists generally claim that the purpose of this section is the demonstration of "replicability," an assertion that Mulkay, Barnes and Gross have found to be largely untrue. The function of methods and materials is not "replicability" but rather validation of argument through a form of emplotment that denies the generally non-linear "progress" of science. Actual lab notebooks are never published, as Cantor points out, reflecting as they do more of the actual messiness of scientific process; what does reach the public is the "retrospective narrative, an impersonal, passive reconstruction which draws attention to those theories, tests and data which are considered appropriate for consumption by the scientific community" (160). Similarly, Lynch argues that the "docile record" of scientific narrative is always produced from the vantage point of the already known results: "the 'what-was seen' at any given point in an experiment is an historicized construct based upon 'what it turned out to be' in the end" (220). In short, the function of the experiment is to produce results of a particular kind; if it does not, the variables need to be recrafted in order to ensure appropriate numerical results; furthermore, the telling of this story needs to select out inappropriate elements in order to retain "clarity": as Knorr-Cetina puts it, "scientific products are 'occasioned' by the circumstances of their production" (124). It is precisely this recursive construction of the experiment and its story that is unarticulated in published writing. [10]

The clarity and linearity of the narrative "flow" are thus understandably central areas for evaluative judgement of student writing. Above all else, a good story must be readable, must through illusion replicate the lived and rational experience of time and causality. The central problem in the "chicken" paper discussed above is its constant "wordy" interruption of the story line, a critique that implies that "words" and stories are opposed-that stories and "truth" are united. Additionally, in spite of such recurrent criticism of the "wordiness" that breaks down coherence, the top rated papers from Introduction to Biology employ far longer sentences (on average 33% longer) than those of papers at the bottom of the ranking system. Furthermore, the successful papers utilize complex sentence forms on a much more regular basis. More specifically, the top ranked papers depend upon introductory clauses and phrases-particularly adverb clauses that reinforce the sense of linear time. In one top ranked paper, for example, (see figure 1 in the appendix) of the twelve sentences total in the methods section, exactly half begin with introductory clauses or phrases that contribute to narrative flow; four of those are actually temporal markers, as in these examples:

— Once this was accomplished, this mixture was drawn up...

— After ten days of incubation.., the tubes were removed..,

— After two hours had passed, the amount of sexual reproduction was determined, etc.

On the other hand, in a paper ranked closer to the bottom of the same set, out of the 26 (highly periodic) sentences total in the methods section (this methods section is only one line longer than in the previously discussed paper), four begin with introductory clauses or phrases, only one of which is a direct temporal marker (see figure 2); one other sentence begins with an implicit reference to previous time, but not in a manner that relates to the experiment itself.

Like the student papers judged to be at the upper end of the grading scale, professional writing within the various branches of biological research evidences a strong tendency toward lengthy sentences dependent on introductory temporal markers, For example, in the methods sections of articles published in the January *1994* issue of *The Journal of Experimental Zoology*, one quarter to one half of the sentences describing the actual experiments began with explicit references to time. Here are sample sentence openings of the methods section of the first article of the issue:

— On each of days 16, 30, and 39 ,...

— Then each group of eggs was exposed....

— On the same days....

— After measurements, eggs were transferred.,..

— They were later thawed.. . .

— Immediately after the O2 concentration...was measured,...

etc. (Kam and Lillywhite 2)

This emphasis on linear emplotment is typical of all the methods sections of the journals I studied. Teacherly criticism of student "wordiness," then, is misleading, implying as it does that word numbers need to be pared down in order for the report to approximate the objective "truth"; in fact, the legitimate discourse of the field places a high premium not on fewer words but on words that enhance the sense of uninterrupted and non-reflexive narrative.

2. "Results and Discussion"

The idealized narrative of the methods and materials section makes believable and convincing the conclusions presented in the results and--more importantly--discussion sections. Results sections generally represent the quantified findings of the experiment reported in methods and materials, As it is put in the style guide to writing a scientific paper, the results section is "an objective report of what happened." Going further, the writer of the guide cautions the student reader that "it does not include your interpretation of what the data imply (save that for the Discussion)." Professional writing reflects this desire to appear to exclude explicit interpretation from results sections; these sections generally combine passive narrative (e.g. "Fluorescence intensity was measured for the 10 brightest epidermal cells per microscopic field at each timepoint"); quantified tables and graphs; and generalized findings (past tense) and "rules" (present tense), with the object studied usually taking the subject position of sentences (e.g. "sea anemone tentacles are composed of two tissue layers separated by a mostly acellular matrix called the mesoglea," and "Fluo-labeled tentacles exhibited fluorescence both in the epidermis and in the gastrodermis" [Mire-Thibodeaux and Watson 338, 339]). The results section thus realizes, in a sense, the narrative direction of the methods; it reflects the "natural" culmination of an (almost) agentless series of events, It is precisely because the results section follows and is thus legitimated by the narrative "methods" that it has become, as Thompson argues of the results sections of published work in biochemistry, "the bastion of 'cold' factual reporting" (107).

The highest ranked student papers for Introduction to Biology clearly employ this tone of natural closure in their results sections. Among the most often repeated words are "evident" and "obvious," used as in this particular paper to construct findings as believable:

— From Figure 1, it is evident that similar rates of sexual reproduction occurred.

— It was obvious both through visual observations and statistical analysis, that C. moewusii was affected by both the depleted nitrogen and phosphorus conditions (emphasis added).

The professor has marked the first sentence "good" and the second "excellent," praising, one must assume, not only the findings but their representation as being only too obvious to any observer. This sense that the events have resolved themselves without human intervention and interpretation is further enhanced through a recurrent placement of the study itself or its attendant charts and tables into the subject positions of sentences (even if awkwardly): "the results suggest that there was much less sexual reproduction occurring in the -P condition than in the others"; "When comparing these two conditions together the statistical analysis suggests that there is no difference in growth between the -P and -N conditions." Gilbert and Mulkay have commented on this type of sentence construction in the context of professional writing; they argue, as do I, that it is in order to minimize explicit mention of the human nature of science that scientists employ verbs usually associated with human agency in the company of non-human 'agents'; [thus] authors construct texts in which the physical world seems regularly to speak, and sometimes to act, for itself' (42, 56). By the results section of a scientific paper, nature stops moving and begins talking; the events flow into their articulation.

Since nature speaks the truth of its own story, the interpretation of the scientist is rhetorically irrelevant; the discussion section is separated off from the actual body of the paper in a kind of endnote. Here the voice of the scientist might come through directly; first person may be used. Yet the voice here is of the person who has seen and heard and then interpreted, in that linear order. This is not the voice of the researcher engaged in a recursively constructed experiment functioning to produce coherent results; it is the voice at the end of the idealized narrative of generalized events. Thus it is not unusual at this point in the professional paper to read sentences that begin "we conclude that. .." or "this may be due to..." or even "we cannot account for this particular data..." (from *Journal of the Pennsylvania: Academy of Science);* these constructions signal human interpretation as separate from the autonomous body of rhetorical time encapsulated in the methods and results. Similarly, top ranked student writing accomplishes the same sense of separation for discussion sections: it moves abruptly from the presentation of the events as rhetorically autonomous to the use of first person and the foregrounding of interpretation, as in this report on the "Recessiveness or Dominance of Mutant Traits of *Drosophila melanogaster":*

> From the Fl offsprings we were able to conclude whether the traits that we saw were dominant or recessive, X-linked or autosomal. The first cross we had mated were round-shaped/ white eyed males with bar-shaped/red eyed females. Since all of the offsprings exhibited round-shaped/red eyed phenotypes, we can conclude that these traits are both dominant and the

> other two traits are recessive. Unfortunately, we had one round-shaped/white eyed son due to chromosomal non-disjunction. The mother did not pass on an X chromosome. Etc.

The student constructs this section to represent the present moment of writing as removed from the narrative of the experiment, a gesture that further naturalizes the already established results. The instructor comment is "Great discussion!" and the paper is judged to be "excellent overall!" The same professor marked as troubling any discussion section from the same set that allowed other sections of the paper to "bleed" into it, or vica versa, The highest evaluative criteria for discussion sections appeared to be the extent to which the writer(s) managed to disengage them from the rest of the paper.

The discussion section, then, which in terms of professional contribution is the most important section of the paper, is enabled by the teleological logic of scientific format;[11] the ultimate pronouncement of human understanding is validated to the extent that it claims to have grown necessarily from the "natural" linearity of the narrative. Alan Gross argues similarly that the linearity of the experimental paper functions to "necessitate" scientific interpretation:

> The sequence of the sections of the experimental paper...has Baconian roots: a steady march from Introduction to Discussion, from the contingency of laboratory events to the necessity of natural processes. This order is, as Woolgar aptly states, "a picture of the discovery process as a path-like sequence of logical steps toward the revelation of a hitherto unknown phenomenon" (89).

This path of scientific knowledge discounts the extent to which results are produced, shaped, and known before they are ever reported and their seamless story told. In the context of discussing Crick's "modest" claim that the discovery of the structure of the DNA molecule was dependent on "nature, not human beings," Gross goes so far as to argue that this Baconian conception of knowledge growing chronologically from mute observation is in fact a myth:

> [Crick's] line of argument fails: . ..the brute facts [did not] point unequivocally in a particular theoretical direction, In fact, in no scientific case do uninterpreted brute facts-stellar positions, test tube residues-confirm or disconfirm theories. The brute facts of science are stellar positions or test-tube residues under *a certain description;* and it is these descriptions that constitute meaning in the sciences.[...] No inductions can be justified with

> rigor: all commit the fallacy of affirming the consequent; as a result, all experimental generalizations illustrate reasoning by example. (11)[12]

"Reasoning by example," however, is rhetorically constructed through narrative forms as "truth and understanding out of the lesson of time." Similarly, Gilbert and Mulkay argue that the ideology of the scientific enterprise in general is dominated by the "truth will out device" of empiricism which posits that the inevitable problems of human intervention will ultimately be swept aside in the Linear and autonomous progress of science (Chapter 5). This "truth will out device," like the format that validates individual interpretation, depends upon a conception of history as progress and a vision of the natural world in the process of realizing itself and articulating that "selfness" to humanity.

IV. Complications of the Scientific Genre:

A. Parodies of Science

The extent to which narrative-particularly teleological narrative-underpins not only the rhetoric but the logic of biology is particularly evident in the clear enjoyment that both students and instructor took in an exercise assigned for a junior- and senior-level course examined for this study. For this exercise, students were asked to parody *Science News* by rewriting an article published in any *legitimate* journal of the discipline. Students responded-&most universally-by stripping the "legitimate" article of its narrative methods section and thus effectively "spatializing" the results (by "results" I mean the substance of both "results" and "discussion" sections, with little to no distinction drawn). The rewritten articles also foreground the author/researcher him or herself and highlight the significance of the study.[13] One of the top-ranked student papers, for example, is titled "Gardeners beware! Fertilizing soil may not be beneficial to your plants" and opens this way:

> Fertilizing soil tends to have negative effects on plant life, says Nancy Collins Johnson from the department of Ecology, and Behavior at the University of Minnesota. Results from her study suggest that adding phosphorus and nitrogen (two important elements in fertilizers) tends to select for fungi, specifically vesicular-arbuscular mycorrhizae (VAM), in the soil that are too aggressive for the host plant which results in a negative effect on the plant's growth.

The instructor comment on this paper reads "Excellent!! Style and

Content are great." Another top-ranked paper "outlines" the findings of the researcher, but apparently includes too much detail, as is noted by the professor: "'This is pretty hilarious, because it's way too obscure and technical for Science News, as I'm sure you realize. But it's just what I'm looking for, in terms of length and style. Great job!"

B. The Biology Major in a Literature Course

The extent to which most junior and senior biology majors have internalized and naturalized the legitimizing features of narrative was made very clear to me in the course of this study when I began looking at student work outside the field of the major. More specifically, I examined the work of senior biology majors taking introductory literature courses to fulfill (that last credit of) general education requirements. Fahnestock and Secor argue that literary criticism as a genre is dominated by an "appearance/reality topos" which relies for its rhetorical force and structure upon "spatial metaphors" such as surface and depth:

> The very notion of appearance versus reality translates immediately into images of a surface with something underneath, of solids that can be proved, of layers that can be peeled away to reveal deeper layers. (85-6)

The biology students generally avoided any such "spatial" constructions and opted instead for a constantly redrawn narrative of the enterprise of writing. This is not to say that the students turn just to plot summary, a form which also relies upon emplotment. On the contrary, the "time" constructed by the student writers is not so much that of the novel, play, or poem but rather that of the argument itself. In other words, the narrative form of the hybrid genre of lab report/literary analysis is self-reflexive, referring constantly back to what the student must do in order to be logically true to the text, what s/he must do next, and what s/he is compelled to do then. This linear progress does not trace the order of her thinking and/or discovery process; it maps the linear process by which a text reveals itself and its meaning to the observant reader.

For example, the openings of the introductory sentences from a typical essay draw constant attention to the emplotment of the following pages:

- In "Night Sea Journey" of Lost in the Funhouse, Barth develops a theme... [quotation]
- I would like to examine several aspects of this theme...
- I will illustrate the way...
- Let us first..., etc.

The student deflects commitment to a "point" in favor of inviting "us" on a journey. He has not constructed this journey, however, so much as studied it, become a trail guide of sorts. Barth-and logic itself-demand the linear order of ideas, and the student is only a detached but perceptive observer. Transitional sentences lead the reader from idea to idea in similar ways, and temporal markers dominate roughly every third sentence of the paper, constantly structuring analysis as chronology, projecting the reader ahead to some (future) point when full meaning and/or understanding will reveal itself. When the time of the paper is not explicitly mentioned, the book itself is generally presented as speaking for itself; our temporal journey is apparently one that takes us to the moments when the text reveals itself. Quotations are "analyzed" in such a way that they do not appear not to be undergoing analysis: thus "it is important to remember" points about the book which should come "as no surprise" because they are so "clearly" "obvious." Only in the final two sentences of the paper does the student articulate his own "point."

V. Conclusion

I have only begun in this essay to show how the appropriation of biological discourse works and what changes the evolution entails. Certainly the process is extremely complicated, influenced as it must be by almost innumerable issues of context (e.g. type of institution; ethnicity, class, gender of students; pedagogy, etc). This brief and naturalistic study can only gesture toward the immense complexity of academic language and discourse acquisition-who is "in" and who is "out," what the unspoken rules of membership are. What the study does show, however, is that the discipline of biology does in fact have such rules, a whole system of criteria for disciplinary membership that goes beyond (that *even* contradicts) the explicit and published expectations for writing in the field, Furthermore, these "rules" for writing speak to the construction of knowledge in the discipline as a whole; their articulation implies an unveiling of the naturalized scaffold that upholds legitimated knowledge. The students who "make it through" the system do so through absorbing without comment-probably without conscious thought-the tone, style, and silent epistemology of this scaffold. What this suggests is that if it is a goal for students to be admitted into the inner circles of tie academy with more democratic intent, then it is essential that faculty across the curriculum become self-conscious themselves about the shape of their own knowledge and articulate that structure for those who wish to learn.

Appendix

Figure 1: Methods

Complementary cultures of *Chlamydomonas moewusii* (+ and - strains), purchased from *Carolina Biological Supply,* were taken from their habitat, which was an agar plate consisting of Alga Gro and water, and put into glass tubes containing different medias. This was done by mixing distilled water on tope of the algal plate with the edge of a microscope cover slip to remove the *C. moewusii* cells from the agar. Once this was accomplished, this mixture was drawn up with a Pasteur pipette, and the tubes with were then inoculated with this mixture of distilled water and *C. moewusii.*

Some of these tubes were used solely for the culturing of the (+) strain and some solely for the culturing of the (-) strain. In these two sets tubes for each strain, several consisted of Bold's Basic Media (B), which was prepared according to the protocol reported by James (1978). Several tubes also contained this media without nitrogen (-N), and the other tubes consisted of Bold's Basic Media without phosphorus (-P).

After 10 days of incubation in an environmental chamber (68 F and 16 hours of light; 8 hours of darkness), the tubes were removed and a cell count in each tube was determined by placing a drop of the media with the *C. moewusii* onto a hemacytometer. Once these cell counts were determined (# of cells/ hemacytometer grid), equal amounts of the + and - cells were combined in a sterile Erlenmeyer flasks. These flasks were then put into the environmental chamber for approximately 2 hours which provided an ample amount of time for sexual reproduction to occur. We used two flasks for each type of medium, with each sample taken from two different randomly selected test tubes of each strain.

After the two hours had passed, the amount of sexual reproduction was determined by using a hemacytometer and counting the number of paired and unpaired cells per grid square (0.05 x 0.05 x lmm3) on a hemacytometer. Of these two randomly selected samples, twenty five counts were taken from each for a total of a hundred counts in each type of medium.

Figure 2: Methods

Both sites were chosen from an area in Micheaux State Forest, on South Mountain in Cumberland County, Pennsylvania. The undisturbed site was named Chimney Rocks. The disturbed site was about a half mile southwest of Chimney Rocks. We chose these two sites because of their obvious differences in landscape and proximity to each other. These two characteristics insured that our results were due only to the disturbance and not extraneous factors. Our disturbed site study was conducted on November 2, 1993, a clear and cool day. The previous weekend, a significant amount of rain had fallen.

Our undisturbed site study was conducted on November 5, '1993, a clear and cold day. The previous two days had been dry and cold.

We roped off three 10 x 10 meter areas in each site, with a rope measured and marked every meter. In each of the two sites, both undisturbed and disturbed, three random areas were chosen for fungal identification. Three random areas were chosen throughout each site to ensure relatively equal representation of the entire site. Disturbed area #1, included short new growth, dead decaying branches and logs, and rocky soil. Area #2, included less new growth, grassy patches of soil, and more decomposing material than in site #1. Area #3, included dead standing trees, rocky soil, and little new growth, Undisturbed area #l, on the top of Chimney Rocks, included large rocks, and various trees. Area #2, included low ground shrubbery, various trees, and rich soil. Area #3, included various trees, grassy soil and lots of sticks and twigs. All three areas within the undisturbed site included a significant amount of leaves covering the ground.

In each of the three areas within the two sites, we searched for any type of fungi. We carefully removed any fungi we found. If the fungus was growing from the ground, we were careful to remove the entire organism. When we collected bracket fungi only a portion of the organism was removed for identification. All fungi were wrapped in separate pieces of wax paper, and differentiated between undisturbed and disturbed site. We used Roger Phillips' *Mushrooms of North America* guide to identify all species.

Notes

1 See, for example, Barnes and Edge, eds., Science in Context; Bazerman, *Shaping Written Knowledge;* Gilbert and Mulkay, *Opening Pandora's Box:;* Knurr-Cetina and Mulkay, eds., *Science Observed;* Latour and Woolgar, *Laboratory Life.*

2 See Belanoff and Dickson, eds. *Portfolios;* Fulwiler, ed. *The Journal Book;* Gere, ed. *Roots in the Sawdust;* Parker and Coodkin, *The Consequences of Writing:;* Walvoord and McCarthy, *Thinking and Writing in College;* Young and Fulwiler, eds. *Writing across the Disciplines.*

3 This oppositional definition of writing styles in the natural sciences and in the arts and humanities is typical. Ernest Nagel, writing in defense of scientific discourse, claims that

> It is not always desirable or useful to diminish the vagueness of language. In poetical discourse, vagueness is often an advantage, rather than a defect. [...] On the other hand, it: is obvious that vague language can be a serious hindrance to the execution of social poIicy as well as to theoretical research. (51-52)

4. See also Collins, *Chaging Order;* Knorr-Cetina *The Manufacture of Knowledge;* Latour and Woolgar, *Laboratory Life;* Lynch, *Art and Artifact in Laboratory Science.*

5. During the spring semester of 1993, I conducted half hour interviews with all seven faculty members of Dickinson's biology department. Faculty were asked to describe 1. the types of writing they assigned indifferent courses; 2. the approach(es) they took to improving student writing; 3. their expectations for student writing at different levels; 4. the most common problems in student writing. Results were written up, returned to the department, and discussed in a faculty workshop.

6. I worry, then, about teachers like Spanier, a biologist who reports that she encourages students to write expressively in the face of rigid discourse conventions:

> A telling illustration of this initial difficulty surfaced when many of the science majors who took my course...had to ask me several times if I *really* wanted them to use "I" in the papers by telling us why they had chosen their topic. . . . With encouragement and reassurance those students wrote excellent papers, in which each one's voice was clear and distinctive, each "I" placed well in the context of the analysis. But to do so, the students had to overcome their training in science-and related disciplines. (204)

7. See also Beer, *Darwin's Plots;* Landau, "Human Evolution as Narrative"; Ree, *Philosophical Tales;* Latour and Strum, "Human Social Origins"; Steve Woolgar, "Discovery"; Lynch, *Art and Artifact in Laboratory Science.*

8. See, for example, Bazerman, *Shaping Written Knowledge;* Bourdieu, *In Other Words;* Voloshinov, *Marxism and the Philosophy of Language.*

9. See de Certeau, *The Writing of History;* Dominick LaCapra, *History and Criticism;* Ricoeur, *Time and Narrative;* White, *The Content in the Form.*

10. Latour argues that this shaping hand will always be ahead of the outsider who challenges the results and interpretations of a scientific study. Interpretation precedes not only the reporting process, in other words, but also experimentation and even the cognitive ability to observe. The "facts" of the "natural world" are always already "spoken for." See *Science in Action.*

11. Aronowitz notes briefly that "Francisco Ayala distinguishes

biology from physics and chemistry by invoking its reliance on teleological. explanations, 'which apply to organisms and only to them in the material world.' [...] Ayala argues that organismic explanations 'cannot be reformulated in non-teleoIogical form without loss of explanatory content., ..teleological explanations cannot be dispensed with in biology"' (307).

12 See also Ernest Nagel: "...it is of central importance to reognize that there is no logical route leading from data of observation to the explanations eventually adopted for them." (15)

13 Myers contrasts what he claims are two different types of narrative in professional and popular biology: *narratives of science* and *narratives of nature*, The former, he argues, "follow the argument of the scientist, arrange time into a parallel series of simultaneous events all supporting their claim, and emphasize in their syntax and vocabulary the conceptual structure of the discipline"; the latter present a sequential narrative "in which the plant or animal, not the scientific activity, is the subject, the narrative is chronological, and the syntax and vocabulary emphasize the externality of nature to scientific practices" (142).

For more on popular science, see also Shinn and Whitley, eds. *Expository Science;* Tourney, "Modem Creationism and Scientific Authority."

A genre shift similar to that from professional to popular biology is embodied in the revisions that must go on between professional biology and the biology text book. See Gaster, "Assimilation Of Scientific Change."

Works Cited

Aronowitz, Stanley. *Science as Power: Discourse and Ideology in Modern Society*. Minneapolis: U of Minnesota P, 1988.

Ball, Carolyn C., Laura Dice, and David Bartholomae. "Telling Secrets: Student Readers and Disciplinary Authorities." *Developing Discourse Practices in Adolescence and Adulthood.* Eds. Richard Beach and Susan Hynds. Norwood: Ablex, 1990. 337-358.

Barnes, Barry. *Scientific Knowledge and Sociological Theory.* London and Boston: Routledge and Kegan Paul, 1974.

Barnes, Barry and David Edge, eds. *Science in Context: Readings in the Sociology of Science.* Cambridge: MITP, 1985.

Bazerman Charles. *Shaping Written Knowledge: Essays in the Growth, Form, Function, and Implications of the Scientific Article.* Madison: U of Wisconsin P, 1988.

Beer, Gillian. *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot, and Nineteenth-Century Fiction.* London: Routledge and Kegan Paul, 1983.

Belanoff, Pat and Marcia Dickson, eds. *Portfolios: Process and Product.* Portsmouth: Boynton/Cook, 1991.

Bourdieu, Pierre. *In Other Words: Essays Towards a Reflexive Sociology.* Trans. Matthew Adamson. Cambridge: Polity, 1990.

Cantor, Geoffrey. 'The Rhetoric of Experiment." *The Uses of Experiment: Studies in the Natural Sciences.* Eds. David Gooding, Trevor Pinch, and Simon Schaffer. Cambridge and New York: Cambridge UP, 1989. 159-180.

Collins, H. M. *Changing Order: Replication and Induction in Scientific Practice.* London: Sage, 1985.

de Certeau, Michel. *Heterologies: Discourse of the Other.* Trans. Brian Massumi. Minneapolis: U of Minnesota P, 1986.

--------. *The Writing of History.* Trans. Tom Conley. New York: Columbia UP, 1988.

Fahnestock, Jeanne and Marie Secor. "The Rhetoric of Literary Criticism." *The Textual Dynamics of the Professions: Historical and Contemporary Studies of Writing in Professional Communities.* Eds. Charles Bazerman and James Paradis. Madison: U of Wisconsin P, 1991.76-96.

Fulwiler, Toby, ed. *The Journal Book.* Portsmouth: Boynton/Cook, 1987.

Gaster, Barak. "Assimilation of Scientific Change: The Introduction of Molecular Genetics into Biology Textbooks." *Social Studies of Science 20* (1990): 43 l-454.

Gere, Anne Ruggles, ed. *Roots in the Sawdust: Writing to Learn Across the Disciplines.* Urbana: National Council of Teachers of English, 1985.

Gilbert, G. Nigel and Michael Mulkay. *Opening Pandora's Box: A Sociological Analysis of Scientists' Discourse.* Cambridge: Cambridge UP, 1984.

Gouding, David. "Empiricism in Practice: Teleology, Economy, and Observation in Faraday's Physics," *Isis* 73 (1988): 46-67.

------. "How Do Scientists Reach Agreement about Novel Observations?" *Studies in History and Philosophy of Science* 17 (1986): 205-230.

Gross, Alan G. *The Rhetoric of Science.* Cambridge and London: Harvard UP, 1990.

Kam, Yeong-Choy and Harvey B. Lillywhite. "Effects of Temperature and Water on Critical Oxygen Tension of Turtle Embryos." *The Journal of Experimental Zoology* 268 (1994): 1-8.

Knorr-Cetina, Karin, "The Ethnographic Study of Scientific Work: Towards a Constructivist Interpretation of Science." *Science Observed: Perspectives on the Social Study of Science.* Eds. Karin Knorr-Cetina and Michael Mulkay. London and Beverly Hills: Sage, 1983. 115-140.

-------. *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science.* Oxford: Pergamon, 1981.

Knorr-Cetina, Karin and Michael Mulkay, eds. *Science Observed: Perspectives on the Social Study of Science.* Beverly Hills and London: Sage, 1983.

LaCapra, Dominick. *History and Criticism.* Ithaca: Cornell UP, 1985.

Landau, Misia, "Human Evolution as Narrative." *American Scientist* 72 (1984): 262-68.

Latour, Bruno. *Science in Action: How to Follow Scientists and Engineers Through Society.* Cambridge: Harvard UP, 1987.

Latour, Bruno and C. S. Strum. "Human Social Origins: Oh Please, Tell Us Another Story." *Journal of Social and Biological Structures* 9 (1986): 169-87.

Latour, Bruno and Steve Woolgar. *Laboratory Life: The Social Construction of Scientific Facts.* Beverly Hills and London: Sage, 1979.

Lynch, Michael. *Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory.* London: Routledge and Kegan Paul, 1985.

Lynch, Michael, Eric Livingston, and Harold Garfinkel. "Temporal Order in Laboratory Work." *Science Observed: Perspectives on the Social Study of Science.* Eds. Karin D. Knorr-Cetina and Michael Mulkay. London and Beverly Hills: Sage, 1983. 205-238.

Mire-Thibodeaux, Patricia and Glen M. Watson. "Direct Monitoring of Intracellular Calcium Ions in Sea Anemone Tentacles Suggests Regulation of Nematocyst Discharge by Remote, Rare Epidermal Cells." *The Biological Bulletin* 185 (1993): 335-345.

Myers, Greg. *Writing Biology: Texts in the Social Construction of Scientific Knowledge.* Madison: U of Wisconsin P, 1990.

Nagel, Ernest. *Teleology Revisited and Other Essays in the Philosophy and History of Science.* New York: Columbia UP, 1979.

Parker, Robert and Vera Goodkin. *The Consequences of Writing: Enhancing Learning in the Disciplines.* Upper Montclair, NJ: Boynton/Cook, 1987.

Pickering, Andy. "Living in the Material World." *The Uses of Experiment: Studies in the Natural Sciences.* Eds. David Gooding, Trevor Pinch, and Simon Schaffer. Cambridge: Cambridge UP, 1989. 275-298.

Ree, Jonathan. *Philosophical Tales.* London: Methuen, 1987.

Ricoeur, Paul. *Time and Narrative. Vol. 1.* Trans. Kathleen McLaughlin and David Pellauer. Chicago and London: U of Chicago P, 1984.

Shim, Terry and Richard Whitley, eds. *Expository Science: Forms and Functions of Popularization.* Dordrecht, Boston, and Lancaster: D. Reidel, 1985.

Spanier, Bonnie. "Encountering the Biological Sciences: Ideology, Language, and Learning." *Writing, Teaching, and Learning in the Disciplines.* Eds. Anne Herrington and Charles Moran. New York: Modern Language Association of America, 1992. 193-212.

Thompson, Dorothea K. "Arguing for Experimental 'Facts' in Science: A Study of Research Article Results Sections in Biochemistry." *Written Communication 10* (1993): 106-28.

Toumey, Christopher P. "'Modern Creationism and Scientific Authority." *Social Studies of Science 21* (1991): 681-700.

Voloshinov, V. N. *Marxism and the Philosophy of Language.* Trans. Ladislav Matejka and I. R. Titunik. New York and London: Seminar P, 1973.

Walvoord, Barbara E. and Lucille P. McCarthy. *Thinking and Writing in College: A Naturalistic Study in Four Disciplines.* Urbana: National Council of Teachers of English, 1990.

White, Hayden. *The Content in the Form: Narrative Discourse and Historical Representation.* Baltimore: Johns Hopkins UP, 1987.

Woolgar, Steve. "Discovery: Logic and Sequence in a Scientific Text." *The Social Process of Scientific Investigation. Sociology of* *the Sciences.* Vol. 4. Eds. K. Knorr, R. Krohn, and R. Whitley. Dordrecht and Boston: D. Reidel, 1981.

Young, Art and Toby Fulwiler, eds. *Writing across the Disciplines: Research into Practice.* Upper Montclair, NJ: Boynton/Cook, 1986.