SCIENTIFIC WRITING AND THE COLLEGE CURRICULUM

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ABSTRACT

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The study of scientific writing--its rhetorical evolution and special rhetorical features--emerged as a scholarly concern during the 1930s. Two major views are evident with regard to the precise origin of the "plain style" in scientific discourse. The camp represented by the ideas of Morris W. Croll and George Williamson holds that the plain style of the modern scientists is rooted in the Classical plain style of antiquity, i.e., that of Tacitus and Seneca. Alternatively, R. F. Jones, Robert Adolph, Richard Halloran, and Merrill Whitburn have argued that the scientific plain style originated as a new prosaic standard developed by Royal Society of London founders in the seventeenth century. In the first chapter, I support the second of these camps and argue for an intellectual connection between the rhetorical theory of Peter Ramus, Francis Bacon, and the plain style strictures adopted by the Royal Society, as articulated by its first historian Thomas Sprat.

In Chapter Two, I argue that the view of scientific

writing as "plain" is too limited and misleading; although referentially such writing is indeed largely concerned with material reality--or "thing-ness"--it is also true that rhetorically it is not concerned solely with technical exposition, but contains argumentative elements as well, whether the audience is specialized or popular. Moreover, in recent years some scientists have produced literary works, especially fiction, in which expository, suasive, and speculative elements are combined. The final chapter focusses on scientific writing as a pedagogical area. I suggest that the study of the rhetoric of science must be a fundamental dimension of the liberal arts curriculum, serving as an integrating tool with respect to the now fragmented nature of undergraduate education. Here I broaden the definition of scientific writing further to include writing about science by those outside the scientific community, essentially arguing that scientific rhetoric is not the exclusive property of scientist-writers. I show how thematic reading/writing units--with a substantial component of scientific fiction by literary artists--can be used to bring together the language and rhetoric of both scientists and humanists to bear on such central modern issues as the place of science in society and the definition of science itself.

To my parents, Jaime and Victoria,
who first taught me the value of
schooling; to my wife Joanne, without
whom I could not have come this far;
and to our children, Raechel, Jonathan,
Julia, and Sarah. With love.

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INTRODUCTION

The issue of the relations between literary art and experimental science was brought into prominence in this century by C. P. Snow's metaphor of "the two cultures," which at once captured the distinctive character of our present-day Weltanschauung and added to the modern lexicon a simple phrase with which to hold up to closer examination the centuries-old problem of clashing intellectual traditions. Literature and science, in Snow's view, are opposite but essential to one another, their historical separation having seriously limited the creativity and growth of both intellectual traditions Importantly, the scientist-novelist cast the problem in educational terms:

> Curiosity about the natural world, the use of symbolic systems of thought, are two of the most precious and most specifically human of all human qualities. The traditional methods of mental development left them to be starved. So, in reverse, does scientific education starve our verbal faculties--the language of symbols is given splendid play, the language of words is

> not. On both sides we underestimate the spread of a human being's gifts.[1]

The ultimate significance of Snow, one might reply to his severest critic F. R. Leavis, lies in his having sparked a deeper, more sustained dialectic in education, particularly within the college curriculum, regarding the relationship of the humanities and the sciences in education and in our lives.[2]

Snow brought to the fore questions of definition, answers to which remain elusive, incomplete, and still in the making. Do poetry and science represent diametrically opposed qualities of the human spirit? Are they different aspects of a single creative process the manifestations of which coexist in a vital tension? Or, is it more accurate to hold that the poetic and the scientific "are fundamentally distinct yet partake of each other in a

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[1] Snow (1964), 62-63. The core argument of Snow's 1959 Rede Lecture on "The Two Cultures and the Scientific Revolution" first appeared as "The Two Cultures," New Statesman, October 6, 1956. Successfully or not, "Snow offers himself as a unique living bridge between the two cultures" (Davis, 1964, 4).

[2] The savage personal attack on Snow by F. R. Leavis (1962) should be remembered only as a failure of nerve on Leavis' part to engage in a more searching and honest (if not more conclusive) kind of dialogue. Two examples that come to mind here are the dinner conversation enacted by Jacob Bronowski (1965) in "The Abacus and the Rose," the three participants being a molecular biologist, a professor of English, and a government education official; and Edwin Schlossberg's (1973) imaginary discussion with Albert Einstein and Samuel Beckett.

manner that implies interdependence . . . a relationship of complementarity rather than of coexistence or conflict"? (Hoare 54, emphasis original). In the sphere of education, such philosophic questions are bound up inextricably with pedagogical theory and practice. The individual and collective response to them by educators is a major shaping force of what is taught, how it is taught, and, ultimately, of the critical lens carried by students into corporate boardrooms, government offices, voting booths, courtrooms, laboratories, the arts, and generally incorporated into their public and private lives.

Educational institutions can and must exercise strong leadership in healing the cultural schism between the arts and sciences. Perhaps it is stating the obvious to say that our schools and colleges, far from being simply a mirror of the culture we live in, are powerful agents of change within that culture. The process of education should lead to the attainment of more than employment or a set of technical skills. The economic and practical urgencies of life notwithstanding, the liberal undergraduate curriculum should draw the learner toward higher levels personal maturation and growth, perceptibly altering his picture of reality toward a greater comprehensiveness; it should engender a multi-dimensional critical perspective which, in cyclical fashion, becomes instrumental to further learning and growth. The struggle

in our century to arrive at a new, post-modern conception of reality, one which explains more truthfully the relationship between two of its great intellectual traditions, places considerable pressure on education to contribute its share in this growth process. By a "post-modern" view of reality I mean a view which is synthetic (perhaps in the Hegelian sense), a sense of reality whose character is neither strictly scientific nor humanistic in spirit, but, in containing elements of each, permits a more holistic outlook.

During the past 50 years, considerable commentary and scholarship has appeared on the relationship between the arts and sciences.[3] One philosophical orientation which I believe holds considerable potential for elucidating the relationship between art and science is the principle of "complementarity," a helpful explication of which is given by Norman Rabkin (1967, 19-26). Rabkin traces the origin of the idea to such physicists as Niels Bohr and J. Robert Oppenheimer.[4] In a lecture at the International Physical

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[3] Examples relevant to English studies range from I. A. Richards' (1925, 1970) distinctions between the scientific and non-scientific uses of language and Marjorie Hope Nicolson's (1956) literature and science "influence" studies to G. S. Rousseau's (1978) historical-critical overview of the field of Literature and Science and the critical essays by Patricia Bizzel (1979) and Robert Connors (1983) on scientism in English studies.

[4] Rabkin attempts to show how a number of Shakespeare's plays--including Hamlet, Troilus and Cressida, and King Lear--"are built on visions of complementarity" (27).

Congress in 1927, Bohr introduced and described the concept of complementarity in atomic theory as "a new mode of description designated as complementary in the sense that any given application of classical concepts precludes the simultaneous use of other classical concepts which in a different connection are equally necessary for the elucidation of the phenomena." In other words, while scientists cannot limit their view of reality by the results of particular experiments they have chosen to perform out of a myriad experimental options, the inferences they do make--while only partially reflecting a more complicated reality--must perforce be expressed in simple, logical, and coherent terms. The chief example to which Rabkin constantly returns deals with the nature of light. The fact that the latter may be seen in one experiment as wavelike and in another as corpuscular does not mean that one or the other view is the more truthful one; our understanding of the physical nature of light is dependent on the complementarity of these two views, since one makes sense in the analysis of certain phenomena and the other "works" in explaining other phenomena. Rabkin points out certain analogies to problems in other areas observed by Oppenheimer:

> Indeed, an understanding of the complementary nature of conscious life and its physical interpretation appears to me a lasting element in

> human understanding and a proper formulation of the historic views called psycho-physical parallelism. For within conscious life, and in its relations with the description of the physical world, there are again many examples. There is the relation between the cognitive and the affective sides of our lives, between knowledge or analysis and emotion or feeling. There is the relation between the aesthetic and the heroic, between feeling and that precursor and definer of action, the ethical commitment; there is the classical relation between the analysis of one's self, the determination of one's motives and purposes, and that freedom of choice, that freedom of decision and action, which are complementary to it.[5]

A key question here with respect to English education, in the context of the relations between Snow's two cultures,

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[5] A recent argument for the complementarity of intellectual traditions--surprisingly, in the relationship between religion and science--is offered by the theoretical physicist and Anglican priest John Polkinghorne (1986). "Reality," writes Polkinghorne,

> is a multi-layered unity. I can perceive another person as an aggregation of atoms, an open biochemical system in interaction with the environment, a specimen of homo sapiens, an object of beauty, someone whose needs deserve my respect and compassion, a brother for whom Christ died. All are true and all mysteriously coinhere in one person. To deny one of these levels is to diminish both that person and myself; to do less than justice to the richness of reality. (97)

is this: How does the notion of complementarity apply to the area of composition studies, and particularly to the teaching of scientific writing in the liberal arts curriculum?

The view that literary art and experimental science are complementary rather than conflicting human activities permits a recognition of several meeting points between English studies and science which, beside comprising an exciting domain of scholarship, are of immediate and vital concern in the classroom. One of these meeting points, a discussion of which is undertaken in Chapter One, has to to with the historical development of the "plainness" ethic with respect to prose style--now coming to be known as "the plain English movement."[6] It seems clear that a major shaping force of English prose style since the seventeenth century has been the linguistic strictures promulgated by the Royal Society of London, as announced by the Society's first historian, Thomas Sprat, in 1667. Thus, it is certainly important for English educators to understand how it is that the experimentalists came to

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[6] The recent history of this movement in government and business is treated in different ways by Halloran and Whitburn (1982) and Janice C. Redish (1985). My own treatment of the subject will consider the possible seventeenth-century scientific basis of the plain language ethic, and agrees with Halloran and Whitburn's historical view. Redish does not address the question of the historical origin of stylistic plainness, except to point out that the current movement in government and business dates to the 1970s.

feel the way they did about the function and style of discourse, and, beyond Sprat, how the scientific view of discourse affects current attitudes toward language and writing. Interestingly, too--and ironically--while the community of scientific scholars collectively disallows rhetoric, science itself cannot function without some sort of rhetorical organization, i.e., a way of using language which permits scientists to accomplish their specific "routine" and broader, long-term ends. By manipulating language, scientists attempt to construct as precisely and convincingly as possible a representation of the world as they see it; in effect, such representations are imaginative rhetorical constructions. The link to complementarity here is evident: Science simply cannot operate without language. More, as Jacob Bronowski (1978) asserts, science is a language; he puts forth the view

> that the method of science, the objectification of entities, abstract concepts, or artificial concepts like atoms, is in fact a direct continuation of the human process of language, and that it is right to think of science as being simply a highly formalized language (49).

According to Bronowski's "constructivist" view of how scientists use language,

> we make, we construct, the laws of nature as we see them. We cut up the environment into things;

> we make groups of things, concepts, classes, and then reconstitute them in different forms of sentences. And the whole of our imaginative process is carried on in this way; that is, our capacity to do this in the brain is built on the fact that we are able to remember in symbolic terms; we are able to attach symbols to our memory and project them forward as foresight, and in this way we are able to manipulate by imagination the environment as it might be. And language is simply a way of doing that which is communicable, but inside our heads we are using this sort of language all the time in order, to put it briefly, to imagine. And imagination is essentially a constructivist activity. (1978, 50-51)

While Bronowski's notion of science as a highly formalized language--one which is shaped by its own rhetorical purposes and constraints--may seem sensible to literary scholars, his contention (and my own) that the "plain" language of science was invented by the Royal Society has been for many years a subject of debate.[7]

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[7] The view that the modern plain style originated with the Royal society is supported by such scholars as Richard Foster Jones, Robert Adolph, and S. Michael Halloran, but has been rejected by Morris W. Croll and George Williamson, who attempted to make a case for the primary influence of the Anti-Ciceronians of antiquity, especially Seneca and Tacitus.

Following my treatment in Chapter One of "The Evolution of Scientific Writing," in Chapter Two I examine and demonstrate "The Rhetorical Range and Diversity of the Scientist as Writer." The central point made here is that scientific writing, far from being isolated from the rhetorical-humanistic tradition, actually is quite immersed in it. This is true even of the more technical aspects of scientific writing. "One of the common misconceptions about language," writes W. Ross Winterowd (1968),

> is that the mathematical `language' of science is not loaded--that it is purely objective and that it carries no emotional overtones. The intimidated college freshman looking at a page in the text for his required course in math would certainly not agree that the precise language of mathematics is `unloaded', and that the simple equation $E = MC^2$ is not perhaps one of the most portentous utterences of our era (1).

Winterowd notes that general semanticists have pointed out that there is nothing wrong with the fact that there exists differences in meaning in our various uses of the same word; thus, "any suggestion that we try to use language neutrally is futile" (2), and not even

necessarily desirable.[8] Still another connection of technical scientific writing to the rhetorical tradition is P. B. Medawar's (1967) assertion that at the heart of the scientific process is the telling of stories, for

> a scientist, so far from being a man who never knowingly departs from the truth, is always telling stories in a sense not so very far removed from that of the nursery euphemism--stories which might be about real life but which have to be tested very scrupulously to find out if indeed they are so. (127, emphasis original)

Beyond the area of technical communication, scientists have engaged (especially since the nineteenth century) in other forms of writing, most notably in the popularization of their work and discoveries.[9] Recent examples are the writings of Isaac Asimov, Stephen Jay Gould, Lewis Thomas, Carl Sagan, and the late Loren Eiseley. Beside the growing importance of popular writing in the scientific life, scientists have also written fiction and poetry, though this is a relatively recent development. Salient examples are the novels of Isaac Asimov, Michael Crichton, and Gregory Benford, and the

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[8] For a provocative refutation of the notion that technical writing is inherently more objective than other kinds of writing, see David N. Dobrin (1985).

[9] See for instance Julian M. Drachman's (1930) historical discussion of scientific popularization.

poetry of astrophysicist Alan Lightman and Czech immunologist Miroslav Holub. This range and diversity of writing by scientists (not to mention such important forms as letters, autobiography, and government policy contributions), shows both the continuity of scientific communication with our long rhetorical tradition--including the complementarity of objectivism and subjectivism in the language--and the inseparability of the scientific life and manners from human values.

Following my treatment in the first two chapters of the evolution and rhetorical richness of scientific writing, in the third chapter--on "The Pedagogy of Scientific Writing"--I turn to the practical concerns of the classroom. Chapter Three addresses the uses of scientific writing in a liberal arts curriculum; first, to demonstrate the fact that science, no less than any other intellectual tradition, cannot operate independently of language. One important question here, for instance, is the stylistic one: Can the importance of clarity and "readability" (Hirsch, 1977) and the uses of "opaqueness" (Lanham, 1974) somehow be reconciled and recognized as each making their unique contribution in all kinds of writing, including scientific prose?[10] Another concern is

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[10] See for instance Merrill D. Whitburn et al. (1978), who report on their classroom experiences with encouraging the use by technical writing students of certain rhetorical devices--with the aim being not only to enhance clarity, but to nourish as well the personal and

the pedagogical uses of scientific writing as a literary theme, rather than as only a prose style. Here I will argue that the scientific fiction and non-fiction written by both scientists and humanists can be used to draw students into the great ongoing dialectic in western culture between literary art and experimental science. This argument is accompanied by specific illustrations with respect to reading/writing strategies.[11] A central part of my aim in the third chapter--as well as of the dissertation as a whole--is to show how reading and writing about the relationship between art and science students can be used to engage students in forming their own conception of the unique role and intellectual limits of the two views of reality as well as of their vital dependence on one another in the search for a holistic view of reality.

The importance of the notion of complementarity as a guiding principle for the undergraduate liberal curriculum is suggested by A. N. Whitehead's observation of the utter

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aesthetic dimensions of writing.

[11] That scientific writing can be taught in a humanistic context is evident in the examples of classroom practice found, for instance, in Teaching Scientific Writing (1978), edited by Stephen N. Judy (Tchudi) for The English Journal. One of the instructors, E. Fred Carlisle, shows for instance that the assumptions we make about the relationship between language and science have certain implications for our teaching practices--especially with regard to the relations between writer and subject, writer and audience, and the writer's value-laden attitudes and his intentions.

fragmentation of the college learning experience. In his Aims of Education, Whitehead writes that there are

> three main roads along which we can proceed with good hope of advancing towards the best balance of intellect and character: these are the way of literary culture, the way of scientific culture, the way of technical culture. No one of these methods can be exclusively followed without grave loss of intellectual activity and character. But a mere mechanical mixture of the three curricula will produce bad results in the shape of scraps of information never interconnected or utilized. (84-85)

Whitehead's argument holds important implications for English as a liberal art, as a subject which offers special opportunities for personal growth through the appropriate structuring of language experiences; more specifically, reading and writing activities can be structured to encourage students to develop for themselves a synthetic, post-modern picture of reality. By "post-modern" I refer to the nascent recognition of the limits of science by a culture whose credo since the seventeenth century has been plus ultra, always more beyond. As Kenneth A. Bruffee (1984) points out, the pressure is not only on humanists to comprehend the scientific point of view, but also, reciprocally, on scientists to understand

what humanism is all about. In a deeply troubled world which is trying desperately to pull itself together, the study of scientific writing--in its historical, linguistic, and rhetorical contexts--can help us begin to repair the ideological wreckage of several centuries of feuding intellectual traditions. "The clashing point of two subjects, two disciplines, two cultures--of two galaxies, so far as that goes--ought to produce creative chances," wrote Snow (1964, 16). Since modern science, like literary art, is rooted in language and the western rhetorical tradition, what better place in the liberal arts curriculum to study and foster their natural co-operation than the English classroom?[12]

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[12] Important here is the concept of "organic English," defined by Stephen N. Judy (Tchudi) in his The ABCs of Literacy (1980) as "a language-based curriculum that takes as its overriding goal providing each student with as many diverse, growth-producing experiences with language as possible" (178). See also the treatments by Judy and Judy (1981) and Tchudi (1986) of writing as a liberal art.

CHAPTER I

THE EVOLUTION OF SCIENTIFIC WRITING

The study of modern scientific writing--its emergence, development, and rhetorical aspects--is a recently established academic specialization, in the making roughly for 20 years.[13] Scholarship and pedagogy in the area have developed through the collective (and sometimes collaborative) efforts of educators in a number of academic "home" departments, including the sciences, history, philosophy, psychology, communication, journalism, speech, and English. In English departments scientific writing is closely linked with, and owes a great intellectual debt to, the field of "Literature and Science." Research and criticism in literary-scientific relations came of age at mid-century, with a rapidly growing body of scholarship and strong representation within the Modern Language Association. By 1951, Marjorie Nicolson could say that "We had sown the wind, and are

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[13] Although scholarly attention to the uses of language by scientists can be found much earlier, such as I. A. Richards' discussion of "The Two Uses of Language" (Chapter 34) in his Principles of Literary Criticism (1925), Leonard Bloomfield's Linguistic Aspects of Science (1939), and Theodore H. Savory's The Language of Science (1953).

reaping the whirlwind."[14] The founding of the Literature and Science field is probably one of at least two major forces (the other being the technologization of our culture) giving impetus to scholarly activity in the area of scientific writing, and to the rapid and widespread development since the 1960s of college courses and programs in science communication and scientific writing.[15]

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[14] In her remarks on the field in The Seventeenth Century (1951, 1-9) and in the Preface to Science and Imagination (1956), Nicolson cites as being among the field's earliest influential works Carson Duncan's New Science and English Literature (1913), I. A. Richards' Science and Poetry (1926, 1935), Arthur O. Lovejoy's The Great Chain of Being (1935), and the essays on prose style by Morris W. Croll and Richard Foster Jones. During the 1940s, the M.L.A.'s Literature and Science group amassed 1,300 titles of books and articles published since 1930 on literary-scientific relations. Other important bibliographies on the relations between literature and science are those by Fred Dudley (1968) and the annual listings in the journal CLIO. Professor Nicolson herself was not only instrumental in forming the M.L.A. group, but trained dozens of scholars in the field over a fifty-year period and "was the first scholar to make the field respectable . . . a valid field for research, publication, and professional advancement" (Rousseau, 1978, 586).

[15] See Lawrence P. Verbit's Directory of Science Communication Courses, Programs, and Faculty (1983). In the introduction of both this second edition and its 1978 predecessor (edited by Verbit, Sharon Friedman, and Rae Goodell), the editors make distinctions between "science communication" (writing for general audiences) and "technical communication" (writing for specialized audiences). "Scientific writing" is identified with technical communication. Yet, the examples of pedagogical approaches in the The English Journal issue I cited earlier (note 11) demonstrate that teaching scientific writing involves much more than teaching laboratory note-taking and technical report writing. My own use of the term scientific writing, as I explain in the second and

Teaching and research in scientific writing, within and without departments of English, coheres around a number of central questions which relate in important ways to the subject of this chapter, such as: What is scientific writing? (To which the writing instructor will quickly add, What is good scientific writing?) How does it differ from other kinds of writing? What are its historical origins? What is its place, respectively, in our culture, in the western rhetorical tradition, in the college curriculum? Such questions do not lend themselves to easy or unequivocal answers; yet, they do identify the field's chief preoccupations, and as such have a definite relation to the present discussion of the evolution of scientific writing.

In attempting to make sense of the origin and development of scientific writing, the question of definition is crucial. What is it, precisely, that we are examining the evolution of? What does the term "scientific writing" mean? One can choose, for instance, to restrict the definition scientific writing to mean journal report-- i.e., to technical scientific exposition in "plain" prose. (Here, as will be seen, one encounters the ongoing argument regarding the relative influence of "Attic" prose or Scripture or London's Royal Society on

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third chapters, is far more inclusive than that of Verbit et al.'s definition.

the rise of the plain prose ethic.) A definition of scientific writing that is limited to technical exposition, however, fails to recognize the even broader extent to which science and rhetoric have been historically associated. In the first place, it is clear scientists write more than exposition in relation to their work--argument and narrative have their important place, too, even in technical writing. Second, scientists do a modest amount of "low-tech" writing, including popular exposition, issue-oriented works on science and human values, autobiography, and even fiction and poetry with scientific themes. Third, a good deal of writing about science (from popularization to fiction) is the work of non-scientists. Fourth, beside evolving as an ostensibly identifiable and powerful prose form, and as writing with a broad rhetorical range produced by scientists and non-scientists alike, scientific writing has evolved, as I indicated earlier, into a academic field of study; as such, it has also evolved into its own niche in the liberal arts curriculum. Scientific writing must be defined, then, without excluding any of these various senses of the term, for each of them is real; each of these senses forms an integral part of the story of the historical development of scientific writing. (The present chapter addresses only the first of these four aspects; the other three are taken up in in the following

two chapters.)

I begin, then, with a consideration of the evolution of scientific writing as a style of prose. The essays on this subject by Morris Croll and R. F. Jones in the 1920s and 1930s served to raise, if not solve, two major issues. The first issue has to do with the precise origin of the scientific style of prose: Is it rooted in the Anti-Ciceronian prose of antiquity, exemplified by Tacitus or Seneca? Or is scientific prose a different and new kind of "plain style," born with the modern scientific revolution of the seventeenth century and, even more specifically, with the fellowship of the Royal Society of London? The second issue, mentioned earlier, is closely tied to the first: Given the assumption that the plain style has become a major prose model in the modern era, the question presents itself: Which plain style? Seneca's? That of religious discourse? The Royal Society's? My intent, I would like to note at the outset, is not to make a special case for a particular phylogenetic influence in the rhetorical development of scientific or "plain" discourse, but rather to underscore the point that, despite the historical rejection of rhetoric by the new scientists, scientific prose has evolved within the western rhetorical tradition.

The scientific prose style was officially born in the third quarter of the seventeenth century, with the

agreement among the fellowship of the newly-chartered Royal Society of London to abide by certain strictures in their "manner of discourse." In the now familiar words of Thomas Sprat, the Society firmly resolved

> to reject all the amplifications, digressions, and swellings of style: to return back to the primitive purity, and shortness, when men deliver'd so many things, almost in an equal number of words. They have exacted from all their members, a close, naked, natural way of speaking; positive expressions; clear senses; a native easiness: bringing all things as near the Mathematical plainness, as they can: and preferring the language of Artizans, Countrymen, and Merchants, before that, of Wits, or Scholars. (History, 113, emphasis original)[16]

The key question which arises here is: Was the Royal Society's "plainness" ethic with regard to prose style something unprecedented, a totally new linguistic attitude and practice, or did it have historical roots and continuity with a rhetorical plain style tradition which is not apparent from Sprat's attack on what he and his

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[16] Robert Adolph (1968, 114-115) points out that the statutes on style discussed by Sprat referred to written discourse as well as spoken, and to non-scientific learned discourse as well. That Sprat's pronouncements on these matters do not represent merely his own views (or those of John Wilkins, for instance) has been shown by Margery Purver (1967, 9-19) in her study of the Royal Society.

fellow experimentalists saw as a vicious excess of speech?

For R. F. Jones, the plain style promulgated by the Royal Society in the 1660s was indeed a new rhetorical development--the genesis of both a modern scientific mode of discourse and of the prose model for the modern scientific age, right up to its continuing unfolding in our own day. Scientific discourse arose, in Jones' view, from the great distrust of language itself fostered by the experimental scientists. It was a radical change in attitude toward language and its functions which lay at the heart of the new philosophers' perception of plainness in written and oral discourse.[17] In his essay "Science and Language in England of the Mid-Seventeenth Century" (1932), Jones writes that the stance of the new scientists

> was that the truth of ideas regarding nature was dependent upon accuracy of language, and that the advancement of science must necessarily wait upon the introduction of greater precision and clarity into the use of words. This linguistic reformation was to be achieved by a constant narrowing of terms through strict definition, and by the employment of words that would be exactly

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[17] And, though Sprat and the Royal Society spoke mainly about learned discourse in all the disciplines, the rather explicit implication in Sprat's History is that it would certainly be patriotic to adopt this style of discourse in our everyday lives--i.e., to make it a norm in society at large.

> equivalent, not to hazy conceptions bred in the minds of men by the loose usage of the past, but to the objective truths of nature. They were seeking an objective rather than subjective, materialistic rather than psychological basis for language. (150)[18]

This new attitude toward language should be no surprise, Jones pointed out, in light of the great advancement of mathematics in the seventeenth century, particularly with respect to refinements in the use of mathematical symbols.[19] Linguistically, what the scientists found most uncomfortable to live with was that, in the established rhetorical tradition, a word could have multiple meanings or the same meaning as other words. "The desire to make the word match the thing," argued Jones, "to be in a

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[18] All page references for Jones are to the volume of essays published in his honor, The Seventeenth Century (1951).

[19] Both the modern conception of truth and the new stylistic ideal were in the making decades before the birth of the Royal Society, in the clear, concise, and pointed expository prose with which Rene Descartes, one of the Society's eventual and most distinguished members, set forth his discovery of a new method of reasoning in his 1637 Discourse on the Method of rightly conducting the Reason and seeking Truth in the Sciences. The cornerstone of the Cartesian system of thought having been provided by modern mathematics, it is this science which Descartes uses in his three appendices to the Method (the Geometry, the Meteorics, and the Dioptrics) to illustrate his new method of objective and logical thinking. As I discuss later, Bacon and Ramus (unlikely bedfellows as they are) were even earler, founding influences on the development of the new plainness ethic.

strict sense a description of a thing or action, explains their exaggerated antipathy to metaphors and figures of speech" (Ibid. 155).

In an earlier essay, "Science and English Prose Style in the Third Quarter of the Seventeenth Century" (1930), Jones held

> that the attacks on the old, as well as the formulation of the new, style find consistent expression in those associated with the new science, that the first organized scientific body in England, the Royal Society, definitely adopted a linguistic platform which exerted a powerful influence on the style of its members even in writings other than scientific, and that the foremost exponents of the new style were members of this society and in most cases deeply interested in science. (76)

As salient champions of the emergent attitude toward language and style, Jones cited such figures as John Wilkins, Thomas Hobbes, Robert Boyle, Thomas Sprat, and John Locke. Wilkins (a mathematician) was among the first of the founding members of the Royal Society to promote the new ethic of stylistic plainness, and, from the standpoint of the history of ideas, he will probably be remembered most for his attempt to establish a universal scientific language based on mathematically precise

symbols. Wilkins' earliest effort to promote a plain style of discourse was in his Ecclesiastes, or, A Discourse concerning the Gift of Preaching As it fals under the Rules of Art (1646), where he declared in the spirit of the new philosophy that the "phrase" in preaching "must be plain and naturall, not being darkned with the affectation of Schollasticall harshnesse, or Rhetoricall flourishes." In his 1668 Essay Towards a Real Character and a Philosophical Language, a work sponsored by the Royal Society, Wilkins tried to establish a language for all learned discourse that was free from ambiguity, a language that would permit description of things and expression of thoughts with the accuracy and clarity demanded by the new science.[20]

The creation of a universal language had been attempted earlier by other members of the Royal Society, as Jones notes. Wilkins, Robert Boyle, William Petty, and the mathematicians Seth Ward and John Wallis assisted Dalgarno in producing such a language in Delgarno's 1661 Ars Signorum, the aim of which, according to Dalgarno, was

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[20] On Wilkins' Real Character, and on other members of the Royal Society--including Robert Boyle, Joseph Glanville, and John Locke--who were especially influential in the shaping of modern prose, see Wilbur Howell (1971), 448-502. With respect to the question of rhetorical origin of the plainness ethic, Howell comments: "A passion for the revival of a merely Senecan plainness in style would scarcely seem able to account for the depth and scope of Wilkins' passion for a new scientific medium of communication" (464).

"to remedy the difficulties and absurdities which all languages are clogged with . . . by cutting off all redundancy, rectifying all anomaly, taking away all ambiguity and aequivocation."[21] Wilkins carried this idea further by attempting, Jones writes, "to classify everything in the universe, and then by a combination of straight lines, curves, hooks, loops, and dots, to devise for each thing a symbol which would denote its genus and species" (155).[22]

The most detailed example offered by Jones of the influence of the new stylistic ideal on non-scientific writings is the series of increasingly plain-styled editions of Joseph Glanville's Vanity of Dogmatizing between 1661 and 1676. Jones compares a number of passages from its first and third editions to demonstrate Glanville's process of "reducing exotic and unusual words, or `hard words', to more natural terms, as well as a constant striving for a simpler, more direct expression" (96). Some of the shorter examples of revision in Glanville's Vanity of Dogmatizing cited by Jones are:

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[21] Quoted by Jones, "Science and Language in England of the Mid-Seventeenth Century," in The Seventeeth Century, op. cit., 154.

[22] While Wilkins was an early influence on establishing the new stylistic orientation, in the first half-century of the Royal Society's existence the most important influence (according to Jones) in the development of the new style was John Locke, who expressed his preference for the plain style in Chapter x of Book III--titled "Of the Abuse of Words"--of An Essay Concerning Human Understanding (1690).

> `Which is to us utter occult, and without the ken of our Intellects' becomes `to which we are altogether stranger'; `those abstrusities, that lie more deep, and are of a more mysterious alloy' = `the Difficulties that lie more deep'; `those principiate foundations of knowledge' = `the Instruments of knowledge'; `Plato credits this position with his suffrage; affirming' = `Plato affirms'; `is a difficulty which confidence may triumph over sooner, the conquer' = `is hardly to be conceived'; `is but as the Birth of the labouring Mountains, Wind, and Emptiness' = `stands yet unresolved'; `preponderate much greater magnitudes' = `outweigh much heavier bodies'. (96)

Jones asserts that Glanville's revisions do not signify a change in ideas, "but an alteration in treatment and expression only": e.g., the "Brownesque inversions" are smoothed out, exclamatory sentences and rhetorical questions give way to direct assertions, sentence length is decreased, unusual Latinisms and exotic words are replaced by more current words, emotional expressions are tempered, and figurative language and poetic imagery are removed. The comparison of the two versions of Glanville's <u>Vanity of Dogmatizing</u> shows, in Jones' view, "not only a change in style but also a vivid picture of

the spirit of one age yielding to another" (97).[23]

Morris W. Croll and, years later, George Williamson maintained, in opposition to Jones' thesis, that the seventeenth century plain style was neither a particularly new nor a particularly scientific writing style. Croll and Williamson saw modern scientific prose as a modified form, a phylogenetic offshoot, of the classical plain style of antiquity, a style exemplified by the writings of Seneca and Tacitus and their modern disciples, Lipsius and Montaigne. In a 1931 review of Jones' above-quoted essay, Croll countered that Jones simplified the more complex rhetorical history involved: "The scientific cult of unrhetorical speech from 1650 onward," insisted Croll,

> was a second, later stage in the history of the same naturalistic tendency that shows itself in the Anti-Ciceronian victory at the end of the preceding century. It did not create a new, a rival style to the Anti-Ciceronian; it only introduced certain changes within the cadres of that style. It was an attempt, a successful attempt, to take the heat and fever out of the imaginative naturalism of Montaigne, Bacon, and Browne, to prune their conceits and metaphors, to

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[23] Jones' other main example, which he discusses in less depth than Glanville, is the stylistic change in Abraham Cowley's writing between his A Vision Concerning Oliver Cromwell (1661) and "The Garden" (1666).

> restrain the wild motions of their eloquence. But it did not change the form and structure of the prose of its time. (Fish, 1971, 91, emphasis original)[24]

In The Senecan Amble (1951), Williamson supports Croll's view of the rhetorical history, and lumps together Sprat's History and Wilkins' Essay, published a year apart, as works holding to the same stylistic doctrine, a doctrine which "ultimately returns to Ecclesiastes, where it is associated with Seneca, not science" (295). It is this Senecan style, persisting from the Anti-Ciceronian movement of antiquity, rather than some new prose style spawned by the modern scientific revolution, which for Croll and Williamson has been the primary shaping force of modern prose.

This difficult question of the precise rhetorical origin of scientific prose remains largely unsettled. For both camps, Bacon's discourse style and stylistic philosophy figure centrally in their respective explanations for the modern reform in prose style, which achieved full strength by the third quarter of the seventeenth century. Both sides agree that Bacon did give shape to the stylistic platform of the Royal Society, but

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[24] Fish's collection contains two of the Croll essays which argue for the Senecan influence: "Attic Prose: Lipsius, Montaigne, Bacon" (1923) and "The Baroque Style in Prose" (1929).

the question lingers as to whether he did so as a Senecan or as a visionary and rhetorically gifted promulgator of a truly novel and modern stylistic ideal, of a new plainness ethic for the scientific age.[25] While Croll, R.S. Crane (Fish, 92-93), and Williamson view Bacon as a Senecan, Jones and a number of others see him and the Royal Society as the creators of a new, distinctly "scientific" plain prose style, a style grounded not on theoretical conceptions and disputations of pre-conceived ideas, but on the independent existence of material reality. Jones' contention that scientific prose constituted a new measure of stylistic plainness is supported by Robert Adolph in his The Rise of Modern Prose Style (1968). For Adolph, scientific writing emerged, like the Royal Society itself, with new Baconian spirit of utilitarianism in the seventeenth century--a spirit which viewed "thing-ness" in a light different from that of the Senecans. "Unlike all the theoreticians of the classical plain style," writes Adolph,

> Bacon means by `things' objective physical reality and its causes, existing before and after the writer's perception of them and independent of him. The Baconian writer, like his ideal

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[25] The studies by Brian Vickers (1968) and James Stephens (1975) are helpful in understanding the surprising differences between the plain style of the new scientists and Bacon's own prose style.

> researcher, submits his mind to these things, rather than constructing a mental edifice of his own according to some ideal pattern or looking within himself to relate the physical world to his own private concerns. But in the classical plain style `things' are intellectual and subjective, not physical and objective. In Croll's words [Style, Rhetoric, and Rhythm, 95], the res are `the candor of the soul . . . the secret experiences of arduous and solitary minds . . . exploring unfamiliar truth by the unaided exercise of its [the soul's] own faculties'. Baconian theory, with its emphasis on the passivity of the faculties, and its distrust of their unguided exercise, is in effect a denial of the classical plain style, as well as Christian mimesis. (168, emphasis original)

However, whether one labels Bacon, in his push for plainness, as a Senecan or Aristotelian, as belonging to the Anti-Ciceronians of his time, or as a Utilitarianist, still does not provide a satisfactory answer to the question of the precise origin of scientific prose and its characterization as a "new" style of discourse. It seems likely that several rhetorical movements or traditions, preceding and contemporaneous with Bacon, all contributed to the making and the taking hold of the scientific plain

style, whether the latter is viewed as a modified classical plain style or as a truly new plain style.[26]

Furthermore, it is noteworthy that beside the classical plain style, there is the tradition of the

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[26] In his 1930 essay "Science and English Prose Style in the Third Quarter of the Seventeenth Century," R. F. Jones distinguished between the stylistic platform of the Baconians and the Anti-Ciceronians by pointing out that

> the desire to discover knowledge which would more fully satisfy the demand for reality was responsible for both revolutions, but the stylistic movements that accompanied them pursued different and divergent courses. The Anti-Ciceronian style found its theories in Aristotle and its models in such Latin writers as Lucan, Juvenal, Persius, Tacitus, Pliny, and especially Seneca; science renounced Aristotle and all his works, and sought for no models in the ancients. Instead of a conscious literary style, such as the other movement was developing, the new philosophy found in the very nature of its material a manner of expression characterized by the lack of literary qualities. The former style, which was far from denying itself the assistance of rhetoric, made use of aphorism, antithesis, paradox, and especially metaphors; the latter, which eschewed all rhetorical flourishes, laid not the slightest claim to these qualities, and against metaphors . . . carried on a constant and uncompromising warfare. Again, neologizing was a distinct characteristic of the Anti-Ciceronians, and freakish Latinisms and strange words were admitted into their works; the scientist, on the other hand, abhorred all such importations, preferring `the language of Artizans, Countrymen, and Merchants' to the "hard" words of scholars. (The Seventeenth Century 104-105, emphasis added)

With respect to "neologizing", it is ironic that, while the new scientists strove for greater simplicity, clarity, and precision in their language, the host of new scientific terms (such as in medical biology) which appeared from the seventeenth century onward had the effect of rendering scientific language a closed system to those outside the sciences (see Savory, 1967, 47-64, on "The Growth of the Language of Science").

Scriptural plain style, which had become established among Puritan preachers by Bacon's time.[27] Though it is difficult to determine the influence of this religious plain style on the discourse style favored by the experimentalists, the same rhetorical revolution that affected the preaching style of the Puritans may also have had a strong facilitative effect on the adoption by Bacon and his disciples of the scientific plain style. The revolution to which I refer is English Ramism, the appeal of which was considerable from the fourth quarter of the sixteenth century to the end of the seventeenth century. More specifically, I mean the logician Peter Ramus' success in promulgating, throughout the English educational system, the view that the art of rhetoric should be concerned only with the third and fifth parts of traditional rhetoric, style and delivery (invention and arrangement belonging under logic). Ramist rhetoric, as George Kennedy (1980) notes, "is a powerful force throughout the seventeenth century in France, England, and Puritan America" (212). To suggest that Ramistic doctrine influenced the Baconians' rhetorical philosophy (or at least that Bacon's rhetorical theory is in certain respects consistent with Ramus's), may seem surprising in

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[27] See Perry Miller (1939, 331-361). Also, Janel M. Mueller (1984, 111-112 and 177-180) notes the Lollard tradition with respect to Scriptural plain style, dating back to the fourteenth century in England.

light of the well-known fact that Bacon was critical of Ramus's method.[28] However, in his study of Ramus' 1577 Dialectique in contrast to Bacon's Novum organum (1619) and De augmentis (1623), Craig Walton (1971) argues that "two chief elements of Bacon's mature writings were chief elements in Ramus' work, and that they were developed in ways remarkably close to those of Ramus" (290-291).[29] If the early evolution of scientific prose style is to be adequately understood, it will be worth exploring here a possible Ramus-Bacon connection in the area, not of logical method, but of rhetorical theory, involving specificially Ramus' reduction of rhetoric essentially to style.

The possibility of a Ramist facilitative role in the

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[28] Kennedy (1980, 216) points out that there are two references to Ramus in Bacon's Advancement of Learning (1605), one of which is by name and complimentary (2.17.12), while the other characterizes Ramus's discussion of method "weakly inquired" (2.17.1).

[29] The two Ramist elements incorporated into Bacon's method on which Walton elaborates are, first, "the definition of and distinction between `invention' and `judgment'," and, second, "a shift of emphasis from formal causes as static definitions of substances and properties to articulation of operative principles as interdependent variables in explanation" (291). For a similar connection between Ramus and one of the founding members of the Royal Society, John Wilkins, see Howell (1971, 454-455), who points out that that Wilkins could have learned of Ramism from William Perkins' 1592 Prophetica, one of the treatises recommended by Wilkins as a supplement to his theory of preaching. According Howell (1956, 206) the first translation of the Prophetica from Latin into English is Thomas Tuke's 1606 The Arte of Prophecying, or, A Treatise concerning the sacred and onely true manner and methode of Preaching.

origin of a modern plain style, one which I now raise, does not appear to have been considered by Croll or Williamson, both of whom stressed the Anti-Ciceronian influence; nor is Ramus mentioned by Jones or Adolph in their studies of the genesis of a scientific discourse model. Given the strong appeal of Ramism in England by time of the Baconian instauration, the unexplored possible relationship between Ramist rhetoric, which emerged in the 1540s, and the scientific plainness ethic evident in Bacon's 1605 Advancement, seems to represent a gap in the study of the intellectual currents bearing on the emergence of a scientific style of prose. Arguments have been advanced for the special influence on the evolution of a scientific prose style of Anti-Ciceronianism, or of the empiricist outlook, or of the plain Puritans, or of utilitarianism. I believe other scholars have missed possibility of Ramus-Bacon connection. Specifically, I will argue that Ramus' reduction in the scope of classical rhetoric to the devices of style facilitated Bacon's usurpation and reconstruction of rhetoric for scientific purposes, and the replacement during the seventeenth century of the Ciceronian stylistic ideal by the stylistic program of the new scientists.

The controversial French educator and logician Pierre de la Ramee (1515-1572), popularly known as Peter (or Petrus) Ramus, "has continued to interest scholars

throughout the centuries," as Peter Sharratt (1987) notes, "especially scholars of rhetoric and logic, and all those concerned with humanism, and with the history of ideas, and, since Ramus attempted to re-organize the encyclopedia of all the arts, with the theory and practice of education" (7).[30] Ramus's interests, as both an educator and scholar were wide-ranging, including grammar, rhetoric, logic, geometry, algebra, arithmetic, mechanics, optics, physics, ethics and religion, "all linked together by his obsession with education" (Sharratt 34). Despite the financial hardship of his early years, he persisted at Paris and in 1536 earned a Master of Arts, following his defense of the thesis that "Whatever is to be found in Aristotle is false" (Duhamel, 1949, 163). Although his radical doctrine was not so much an attack on Aristotle himself than on his medieval disciples, his reform efforts--directed widely throughout the liberal arts field--resulted in a new program for teaching the trivium, and his treatment of rhetoric, as written out by his close associate Audomarus Talaeus (or Talon), enjoyed a strong

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[30] Beside Sharratt's bibliographic essay, especially helpful background sources in my discussion of Ramus and his influence have been Duhamel (1949), Howell (1956, 146-281); Nelson (1947); Ong (1958, 1971), and Tuve (1947, 331-353 and 384-388). Other important sources, particularly with respect to Ramus and Bacon, are cited in the following pages.

following in England.[31]

For the present context, the important aspect of Ramus's reform of the logic, rhetoric, and grammar taught in his time is that, motivated by what he saw as a theoretical redundancy and indecisiveness in these fundamental liberal arts, he ordained that instruction in invention and arrangement be assigned to logic only, and that the study of rhetoric be limited to style and delivery; grammar was to be concerned with etymology and syntax. This new system, in Ramus's view, allowed logic and rhetoric to work together like the head and heart in the expression of our thought, and corresponded to the

> two universal and general gifts given to man by nature, reason and speech. The first is the concern of dialectic, the latter of grammar and rhetoric. Dialectic seeks to establish the all-round strength of the human reason in the discovering and disposing of matter. Grammar seeks the purity of speech in the words and syntax to speak or write well. Rhetoric demonstrates how to ornament an oration with tropes and figures and the dignity of proper

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[31] Evidence of the popularity and persistence of Ramus's rhetoric in England between the 1570s and the early eighteenth century can be found in Howell, 1956, 247-280.

delivery.[32]

It is in this ordained theoretical split between logic and rhetoric, with no overlap in their respective aim and scope, that the Ramist system departs most significantly from the classical tradition of Aristotle and Cicero. Ramus would not grant the possibility that the four great Classical procedures for producing a communication could constitute one process in dialectic and another in rhetoric, settling for him the confusion between rhetoric and logic--a confusion which he attributed to Aristotle and which he felt was magnified by Cicero and Quintilian.[33] Before turning to the matter of Ramus's influence in England and, specifically, on the Baconians,

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[32] Translated by Duhamel (1949, 163) from Ramus's Rhetoricae distinctiones in Quintilianum (1559).

[33] Howell (1956) points out that it is in the French version of Ramus's 1543 Dialecticae Libri Duo that he states most firmly the essential point in his reform of scholastic logic and traditional rhetoric. In the Dialectique (1555), Howell writes, Ramus indicates "his belief in one system of logic for both science and opinion, and in one theory of invention and arrangement for both logician and rhetorician, whereas the scholastics, following Aristotle and Cicero, preferred two systems of logic, one for science and the other for opinion, and two systems of invention and disposition, one in the field of scientific and the other in the field of popular discourse" (155). A delineation of the historical, logical, practical,and natural factors which led Ramus to make what he did of the arts of logic and rhetoric can be found in in both Howell (1956) and Duhamel (1949). In the division between logic and rhetoric which he adopted, Ramus was a disciple of Rudolph Agricola--whose most influential work (written in the 1470s or 1480s) was De Inventione Dialectica--and of Agricola's own disciple, Johannes Sturm, whose lectures he attended at Paris.

I note again that the limitation of rhetoric to style and delivery (the latter largely ignored by later Ramists) was formally established by Ramus's friend and collaborator in educational reform, Talaeus, whose intention in his 1544 Institutiones Oratoriae (known also as Rhetorica) was to do for rhetoric was Ramus had done a year earlier for logic:

> Peter Ramus cleaned up the theory of invention, arrangement, and memory, and returned these subjects to logic, where they properly belong. Then, assisted indeed by his lectures and opinions, I recalled rhetoric to style and delivery (since these are the only parts proper to it); and I explained it by genus and species, (which method was previously allowed to me); and I illustrated it with examples drawn both from oratory and poetry. Thus these present precepts are almost wholly in words drawn from those authors; but as this first and rude outline has unfolded, the precepts have been tested by the judgment of both of us, and disposed in order, and ornamented and treated by kind.[34]

The spread of Ramism in England, as a number of authors have shown, was rapid, wide-ranging, and by no

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[34] Translated by Howell (1956, 148-149) from Talaeus's 1544 preface to the Rhetorica.

means a frivolously regarded phenomenon, affecting various aspects of English cultural and intellectual affairs, including the mechanical arts, historiography, jurisprudence, political science, and religion (the Puritans embraced Ramus's reform efforts). In the universities, interest probably began with Gabriel Harvey's 1575 and 1576 lectures (partly published in 1577 as the Rhetor and the Ciceronianus) on Ramist rhetoric at Cambridge, which were guided by the chief purpose of instituting the Ramist re-distribution of the five great arts of Ciceronian rhetoric, making numerous references to Agricola, Sturm, Ramus, Talaeus, and Foclin (author of a 1555 French translation of Talaeus's 1544 Rhetorica). Other English editions, translations, and interpretations of Ramist rhetorics include Dudley Fenner's The Artes of Logike and Rethorike (1584),[35] Abraham Fraunce's Arcadian Rhetorike (1588), John Barton's The Art of Rhetorick Concisely and Compleatly Handled (1634), Alexander

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[35] This anonymously published work consists of a translation of the main heads of Ramus's 1556 Dialecticae Libri Duo (the briefest Latin expression of his logic) and the first English translation of the main heads of Talaeus's 1544 Rhetorica. As Ong (1949-1953) has shown, Fenner's 1584 Rethorike was one of three anonymous units of a 1651 work titled A Compendium of the Art of Logick and Rhetorick in the English Tongue, the other two units being Robert Fage's translation of Ramus's Dialecticae Libri Duo and Thomas Hobbes' English abstract of Aristotle's Rhetoric. Remarkably, according to Father Ong, the Rethorike of Fenner appeared in 1681 as an anonymous Art of Rhetorick appended to Hobbes' condensed version of the Rhetoric of Aristotle, and until 1951 was accepted as part of Hobbes' canon.

Richardson's notes on "Talaeus his Rhetorick" in his Logicians School-Master (1657), and John Newton's An Introduction to the Art of Rhetorick (1671). The popularity of Ramist rhetoric is also evident from its widespread incorporation in texts for schoolchildren, the most famous example (and one of the leading textbooks of the seventeenth century) of which is Charles Butler's Latin version of Talaeus, Rhetoricae Libri Duo (1598); Butler inspired such treatments of Ramist rhetoric for schoolchildren as William Dugard's Rhetorices Elementa (1648; fifth ed. by 1657), presenting Talaeus's rhetoric in the form of a catechism, Charles Hoole's A New Discovery of the old Art of Teaching Schoole (1660), and the 1671 Rhetorick of John Newton mentioned above. Even into the early eighteenth century, interest in Ramist rhetoric is evident in such publications as a ninth edition of John Smith's 1657 The Mysterie of Rhetorique Unvail'd in 1706 and an abridgement of the latter by one "J. H., Teacher of Geography" in 1739. What I have wished to show thus far in my discussion of Ramist rhetoric is that for well over a century (between Gabriel Harvey's lectures on Ramism at Oxford and John Newton's catechism of Talaeus for schoolchildren) the view was popular in English schooling that the art of rhetoric consisted essentially of a consideration of the third part of Ciceronian rhetoric--of the tropes and figures that

"adorn" the real substance of discourse, which is generated and ordered using the principles of logic.[36]

What does all this have to do, then, with the evolution of scientific prose (and, indeed, of a scientific rhetoric)? Short of providing conclusive and irrefutable evidence of a Ramist influence on the new scientists' style of prose and view of rhetoric, the difficult question of influence can be approached by underscoring certain aspects of Ramist rhetoric which (as I hope to illustrate momentarily) are reflected in the function given to rhetoric, and the attitude adopted toward language and communication, by the New Philosophers. First, I call attention to the fact that, unlike the earlier "stylistic rhetoric" tradition which had only emphasized style,[37] Ramist rhetoric made style

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[36] "In the period between 1600 and 1621," according to Howell (1956), "the English Ramists had almost no rivals among their own countrymen in the the dissemination of rhetorical ideas . . ." (364).

[37] Examples of early stylistic rhetorics include the anonymous Rhetorica ad Herennium (the oldest extant Latin treatment of rhetoric and prose style), Cicero's Orator and De Oratore, Quintilian's Institutio Oratoria, the Venerable Bede's Liber de Schematibus et Tropis (the first stylistic rhetoric written in England, circa 701). In his treatment of "The Rhetoric of Style," Howell (1956, 116-137) identifies these works as part of "a recognizable and distinctive pattern of traditional rhetorical theory in England . . . openly committed to the doctrine of style as the most important aspect of training in communication," though also "openly mindful that invention, arrangement, memory, and delivery, or combinations of two or more of them, conceived in sum as Cicero had anciently dictated, were also legitimate parts of the full rhetorical discipline" (116). Howell's treatment of stylistic

the whole of rhetoric (delivery was essentially forgotten), thus degrading the art itself. As Norman E. Nelson (1947) notes, "anyone who has respect for the art of oratory as the all-important instrument of free and democratic institutions

> cannot help but hold Ramus in part responsible for separating logic from rhetoric in such a way that the inventional or logical part of oratory, which was to Aristotle the whole of the art, was removed, leaving rhetoric nothing but stylistic. Anyone who has read the pitifully dull manuals of schemes and tropes which constitute most of the so-called rhetorics of the Renaissance must be saddened to see how a great art of civilization has fallen till it deserves Socrates' insulting comparison to the `knack' of cookery. (17)

Significantly, despite the fact that interest in Ramus's educational and rhetorical doctrine dropped off markedly in England by the last quarter of the seventeenth century, the practical interchangeability of the words "rhetoric" and "style" had by this time become a culturally-entrenched perception (one that has persisted to the present). The scenario I picture here is one in which

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rhetoric ends with Henry Peacham's 1577 The Garden of Eloquence, "the last English treatise on the tropes and figures to appear in print before 1584, when the earliest English version of Ramistic rhetoric was published" (137) --i.e., Fenner's translation of Talaeus.

this general perception of rhetoric as style only (a degenerated and weakened rhetoric), coupled with the new attack against a Ciceronian superfluity of discourse, immensely facilitated the Baconians' rejection--indeed, their utter denial--of traditional rhetoric. The modern scientists (Bacon among them in his thinking and spirit if not in actual practice) attempted to overpower, and to do away with, even the little that had been left to classical rhetoric by Ramus, style itself, and in the process to substitute a new scientific rhetoric. The details and consequences of this proposed scenario can be appreciated more fully with a closer look at Bacon's Advancement.

It will be useful to begin with W. S. Howell's (1956) perspective on the crucial role played by the Advancement in the development of a new rhetoric:

> This remarkable work, which influenced English learning of the seventeenth century as did no other contemporary work, contained some ideas on rhetoric which were in opposition not only to Ramistic theory but also to the traditional rhetoric of the early Renaissance. This opposition grew as the seventeenth century advanced. The Royal Society, which carried out scientific investigations in the manner proposed by Bacon, and which was to some extent the finest result of Bacon's pioneering thought, had finally

> to develop a system of communication suited to the transfer of information from one scientist to another, and from scientist to public, and the rhetorical theory which underlies that system is a step towards the creation of a new rhetoric. (9, emphasis added)

Emphasized here are the few, but important, words with which the present discussion of Ramism, style, and modern science does not wholly agree. Actually, Howell himself says something significantly different from this, and in my own view more accurate, when later in the same work he characterizes Bacon as a figure who "stands as a composite of scholasticism, of Ramism, and of something that looks to the future" (375, emphasis added). Such differing and in a sense contradictory views seem to reflect an incomplete state of understanding regarding the question of the precise historical relationship--on such levels as ideology, rhetoric, and practicality--and in such spheres as education and science--between Ramus and Bacon. Moreover, studies dealing with the Bacon-Ramus connection focus mainly on differences in their systems of logic and method, on their respective dialectics, with essentially no consideration given to the possible connections in the context of rhetorical history.

Lisa Jardine (1974), for instance, is representative of the currently popular view regarding the existence of

any connection between the dialectics of Bacon and Ramus when she writes that

> as far as Ramism is concerned, whilst clearly aware of Ramist controversy (he alludes to it as having moved a `controversy in our time' [III, 403], and criticizes some specifically Ramist texts), Bacon's only direct borrowing appears to be his use of the word `axiom' atypically as Ramus uses it, for any proposition used as a premise for argument" (8).

While Bacon generally did not find Ramism very palatable, this is not necessarily so with regard to Ramist rhetoric. In his reform of rhetoric, Ramus seems to have set out, in the same stock-taking spirit as Bacon, to deliberately change the stylistic orientation of learned and/or popular discourse. The Bacon-Ramus rhetorical connection, if in fact it is real, involves the crossing of intellectual paths at the right time and place to potentiate an already growing reaction to orthodoxy and tradition. I hope to be able to show in my brief consideration of Bacon's Advancement that Bacon appears not to have been wholly anti-Ramist, as seems widely held, and that Bacon's conception of rhetoric is actually Ramistic in outlook.

As aleady mentioned, for Bacon, and certainly later in the century for Sprat and the Fellowship of the Royal Society, traditional rhetoric came to mean a waste and an

abuse of language, both because of what they perceived as an excessive verbiage in the expression of thought--i.e., a emphasis on words for their own sake--and a lack of sound matter about which to communicate.[38] Thus, in Book II of the Advancement Bacon reproves those who, in the Renaissance tradition of stylistic rhetoric, pursue to excess a Ciceronian charm and copiousness in their discourse, leading them to

> hunt more after words than matter: and more after the choiceness of the phrase, and clean composition of the sentence, and the sweet falling of the clauses, and the varying and illustration of their works with tropes and figures, than after the weight of matter, worth of subject, soundness of argument, life of invention, or depth of judgment. (119)[39]

This view of rhetoric, or essentially of what was left to rhetoric by Ramus, is the driving force behind Bacon's own

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[38] While here we are dealing with the 100-year period encompassing both English Ramism and the Baconian instauration--roughly 1575 to 1675--it should be noted that Bacon's re-definition of traditional rhetoric, Ramist elements included, only grows in importance over the centuries, both for modern science and in the eyes of western culture generally, with the great influence of the ideas of such figures as Rene Descartes, Isaac Newton, and John Locke, as well as with the great accomplishments of modern science itself.

[39] Page references are to the edition of the Advancement by Spedding, Ellis, and Heath (1864-1874).

attempt to reform rhetoric.[40] In the second book of his treatise (260-300), Bacon re-distributes the major parts of Ciceronian rhetoric and uses them in a wider context than any single discipline, while limiting the term rhetoric itself to a rationally-ruled utilitarian function. This limited function of rhetoric is assigned to his modified concept of the Ciceronian art of delivery as "the expressing or transferring of our knowledge to others" (282), to which Bacon also refers as Elocution (the traditional term for style) and Tradition.[41]

Bacon's treatment of Tradition is partitioned into its Organ, its Method, and its Illustration--functions which are carried out, respectively, under Grammar, Logic, and Rhetoric. When he comes to his consideration of Illustration, the specific role of which is to make knowledge clear to its intended audience,[42] Bacon first

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[40] Especially helpful here are the studies by Charles Whitney (1986), James Stephens (1975), and Karl R. Wallace (1943).

[41] "The Intellectual Arts are four in number," Bacon declares, "divided according to the ends whereunto they are referred: for man's labour is to invent that which is sought or propounded; or to judge that which is invented; or to deliver over that which is retained. So the arts must be four; Art of Inquiry or Invention: Art of Examination or Judgment; Art of Custody or Memory; and Art of Elocution or Tradition" (260-261, emphasis original).

[42] It is Howell's view that Bacon's "chief contribution to modern rhetoric consists in his theory of tradition, and in his emphasis upon rhetoric as the supreme illustrator of knowledge for any audience, learned or popular" (375, emphasis added).

acknowledges and praises the Rhetorics of Aristotle and Cicero. "Notwithstanding," he then writes, "to stir the earth a little about the roots of this science, as we have done of the rest:

> The duty and office of Rhetoric is to apply Reason to Imagination[43] for the better moving of the will. (297, emphasis original)

Karl R. Wallace (1961, 115) has suggested that the core of Bacon's entire rhetorical theory may be encompassed by the just-quoted sentence paired with the following one from Bacon's 1623 De Augmentis:

> Rhetoric is subservient to the imagination, as Logic is to the understanding; and the duty and office of rhetoric, if it be deeply look into, is no other than to apply and recommend the dicates of reason to imagination, in order to excite the appetite and the will. (Works, IV, 455)

Essentially, in Bacon's scheme of the intellectual arts, rhetoric assumes a subservient, diplomatic role in enabling the forging of a stable alliance between Reason and Imagination, thereby preventing the latter from associating itself too closely with the passions and

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[43] The editors' own footnote here reads: "Rhetoric being to the Imagination what Logic is to the the Understanding."

causing the will to act irrationally (Howell 371-372).[44]

It is here, finally, that we encounter the Ramist association with Bacon's rhetoric. "By viewing the imagination and reason as definitely distinct faculties," notes Edward P. J. Corbett (1971) in his condensed survey of rhetoric,

> Bacon lays the groundwork for the great amount of subsequent discussion about the separate provinces and the separate cultivation of these faculties; and of course he is thereby fostering the Ramistic dichotomy between logic and rhetoric. (613, emphasis added)

It is this Ramist separation of logic and rhetoric which left to rhetoric and imagination a relatively minor place in learning and discourse--while of course considerably elevating logic--that explains not only the new place and scope in learning allowed by Bacon to rhetoric, but Bacon's views on discourse style as well. Bacon actually adopts and preserves Ramus's view of rhetoric as being essentially the handmaiden of logic, a view which forms the basis for his advocating that style was to be at the service of res rather than verba.

Here we encounter again the new passion for--and, in

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[44] By "excite the appetite and will" (my emphasis) Bacon seems to mean not excitation in an emotional sense, but rather intellectually, "appetite" referring to curiosity.

due time, faith in--"thing-ness" and practicality which, as Adolph (1968) argues, arose with the period's utilitarian spirit. It should be noted here that the modern spirit of utilitarianism holds an important place in the educational ideology of both Ramus and Bacon. Bacon's sense of practicality and utility is clear not only in his Advancement, but also in his unfinished utopian tale The New Atlantis (published almost 20 years after the Advancement), with its detailed picture of the scientific activities of Salomon's House, the end of which is the useful application in society of the results of scientific experimentation. Ramus's utilitarian spirit, on the other hand, manifests itself differently. For instance, one of the guiding principles of the French educator's reform of the liberal arts involved his adherence to a naturalistic practicability which insisted that every art should imitate nature. As Duhamel (1949) has noted, a substantial part of the rhetorical and logical examples used by Ramus "are taken from `nature', from the orators and poets, instead of being manufactured to illustrate theoretical principles" (168). For Ramus, quoting from Vergil or Cicero gave to his logic and rhetoric a certain objectifiable thing-ness, analogous in texture and feeling to the importance for the new scientists of physical nature. Anthony Grafton and Lisa Jardine (1986) express the broader, more fundamental sense

in which Ramus's ideas for educational reform are associated with utility (a sense different from Bacon's materialistic one) when they write that it was

> natural for Ramus to make his practical interventions into contemporary intellectual debate in the form of a revised programme of education--one centered on grammar and dialectic (probabilistic argument), and aimed at proficiency in that range of arts skills which will make the product of his school an able and active member of contemporary society. The `new philosophy' of the school of Agricola and Erasmus makes utility its main criterion for success: utility being taken to mean, productive of the kind of competence which will make an individual a responsible, moral and active member of the civic community. (163, emphasis original)

These examples of Ramus's concern with usefulness and practicality seems to be precisely the context in which R. Hooykaas stated that ". . . with Ramus we see the transition from the `literary empiricism' . . . of the humanists to the `scientific empiricism' of Bacon."[45]

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[45] Quoted by James J. Murphy (1977) in his review of Ramus's 1549 Rhetoricae distinctiones in Quintilianum (Arguments in Rhetoric Against Quintilian). Ong (1971) has pointed out that the Ramist passion for logical analysis of utterances, including those of the poets, had the consequence of fixing attention on the written word rather than the spoken word, which fixation "makes human

Ultimately, then, the limitation of rhetoric to style by Ramus had the effect, first, of isolating--and thereby of drawing more negative attention to--not only style itself, but to the Ciceronian manner of discourse which was becoming offensive in a utilitarian age; and, consequently, of facilitating Bacon's own usurpation and transformation of rhetoric which, at least on the surface, allowed precious little room for eloquence. Ramus gave Bacon impetus and justification for promulgating a style ruled by the dictates of logical reasoning (though Bacon and his disciples would not have consciously referred to the new scientific manner of discourse as a "style"). In any event, the great exemplars of logical reasoning over the past three centuries came to also represent, not by accident, the new models of prosaic plainness: such works as Rene Descartes' Discourse on Method, Isaac Newton's Principia, John Locke's Essay on Human Understanding, and

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expression less a conveyance of a truth or of wisdom and more of an object upon which one performs an operation. Ramist analysis strengthens the tendency to regard the word as a thing" (162, emphasis added). Also, that Ramus's application of the concept of utility differed from Bacon's ought not blind us to Ramus's apparent captivation by the era's scientific spirit, in the form of his rather serious, if only modestly successful, involvement with modern mathematics; see for instance John F. Daly's (1973) discussion of Ramus's Arithmeticae Libri Duo and Scholarum Mathematicarum Libri Unus et Triginta, both published in 1569. Duhamel (1949) points out, too, that Ramus's interests were not limited to the "exoteric" arts (grammar, rhetoric, and dialectic), and that of the "esoteric" or "acromatic" arts (mathematics, physics, and metaphysics) he favored mathematics, although he did write a Scholarum Physicarum and a Scholarum metaphysicarum.

Charles Darwin's Origin of Species.[46] In the end, the connection proposed here between Ramus and Bacon is an ideological one, as historical pieces to the puzzle of the evolution of a scientific prose style. When Ramus weakened the intellectual power of classical rhetoric by limiting its scope to stylistic ornamentation, Bacon's attempt to "stir the earth a little about the roots" of classical rhetoric was made that much easier by his only having to center his critique chiefly on stylistic philosophy and practice.[47] Essentially what

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[46] These works are "plain" in the sense that they rely on illuminating their subject matter by the principles of logical (inductive and deductive) reasoning as applied strictly to natural phenomena, with a rhetorical style that is straightforward. However, as will become apparent in the following chapter, the works of such writers, and of scientific writing more generally, turn out upon closer scrutiny not to be so thoroughly plain, and, on the contrary, actually to depend in important ways on metaphorical expression, among other rhetorical devices.

[47] As to the question of any direct influence of Ramus on Bacon, Craig Walton (1971) notes that while he has found no evidence that Bacon actually read Ramus's original works,

> not all of Ramus' thought was lost to the Ramists, who in turn greatly shaped the schools in Bacon's lifetime. There is circumstantial evidence that Bacon grew up in an atmosphere of Ramist interpretation and critique, and that Ramus' stipulative definition of "invention" as first-order discovery, a usage counter to its usage in the history of rhetoric, was understood and employed artfully in England, e.g., by Milton. (294)

According to Howell (1956), by the 1580s Scholastic logic in England was replaced by Ramism, the latter dominating the British grammar schools over Bacon's lifetime and throughout the seventeenth century.

Bacon sought for science, and later Sprat and Wilkins sought for the English tongue generally, was a style of discourse that was to be appreciated not for its beauty of expression, for the words themselves, but for its effectiveness in conveying natural facts in the straightforward, unadorned, concise, carefully measured wording required to convey those facts. Rationality, not stylistic virtuosity, was to be the hallmark of modern discourse. From the seventeenth century onward, the Ciceronian style isolated by Ramus was to be engaged in a perpetual Battle of the Styles (to paraphrase Swift) with the new plain style of the Baconians.

However, the crucial point for our purposes regarding the attempts by both Ramus and Bacon to subvert by reformulation the rhetorical tradition is that it is clear that the activity and language of science did evolve in a rhetorical context, though the scientific community has not consciously conceptualized its discourse as such; and, moreover, that scientific prose, beyond its technical aspects associated with experimentation or theory, indeed does have a style--one suited to its own needs. (The second chapter discusses at greater length the rhetorical context of the scientist as writer and illustrates the range of rhetorical artistry exhibited in scientific writing.) Bacon's re-structuring of the intellectual arts did not diminish the importance of rhetoric in modern

scientific learning. On the contrary, as Charles Whitney (1986) shows, in reducing the scope of rhetoric to the "illustration of tradition," Bacon actually "imported the traditional rhetorical principles into the more central intellectual arts" (66). The result is the substitution for the traditional art of a concept of "scientific eloquence," a

> special Baconian non-eloquent eloquence [which] aims most of all to preserve Cicero's link between thought and expression, word and thing. . . . For Bacon it is no longer poetry and oratory but the reporting of scientific truth that retains a privileged link to the processes of discovery and observation. (Ibid. 67)

R. S. Crane (1967), like Whitney, notes the importance of rhetoric in Bacon's reformed scheme of the sciences, giving specific examples of how that Bacon adapted traditional rhetoric to the needs of the experimentalists. Crane writes that Bacon constantly

> draws upon the analogy of the humanistic discipline of rhetoric to indicate the subject matter and function of various particular sciences. The parts of what he calls rational philosophy are themselves the traditional parts of rhetoric (invention, arrangement, memory, elocution) . . . the new method of scientific

> discovery by which he sets such store is in its essential features (for example in its use of general commonplaces of sameness, difference, degree, etc., to organize and interpret instances of heat) an adaptation to the investigation of things of the old rhetorical technique of topical invention, which . . . was recommended by Quintilian, Vives, and Elyot. (64-65)[48]

Clearly, then, scientific prose evolved in a rhetorical context, regardless of whether or not recognition and acceptance are accorded to that context. The role of the rhetorical arts in scientific learning and discourse turns out to be, unsurprisingly, no less vital than its role in any other realm of human thought and activity. Both the humanistic and the scientific realms of inquiry depend, after all, upon language; what is "true" in each, the making of knowledge in each, takes on meaning in language--visual, oral, and (the present concern) written.

As to the more specific question of the degree of scientific influence on the modern era's stylistic orientation (and view of the function of style in discourse), this is an important issue associated with the evolution of scientific writing which, like the question of the origin of scientific prose, remains unsettled. By

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[48] See also Wiley (1971), whose extreme argument reduces Bacon's science to rhetoric.

some accounts of intellectual history, the discourse style of the traditional-humanistic culture has faced a losing battle with the style embraced by the new scientists. In this view, scientific prose stands as the stylistic model of the modern age. For instance, in his History of Modern Culture (1930, 1934) Preserved Smith claims that the new science is one of the two major shaping influences on modern language and literature (the other being democracy), and that by the eighteenth century there is ample evidence of the effect on prose style of its infection (note Smith's illness metaphor) by the "virus of science":

> Prose became less majestic, less artfully involved, less emotional and ornate, but more lucid, easier to read, and better fitted for exposition and narrative. The pampered metaphors and far-fetched vocabulary of Sir Thomas Brown were pruned to the simple directness of Swift; the majestic thunder of Milton's periods was reduced to the ordered perspicuity of Dryden's sentences; the rugged and brutal power of Hobbes was subdued to the smooth evenness of Locke; the demonic outpourings of Cromwell were refined to the polished glitter of Bolingbroke's verbiage.[49]

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[49] See Smith's (1934) discussion, "The Modern Prose Style" (Chapter IX), 273-320.

In The Seventeenth Century Background (1934), a study of the influence of the seventeenth century scientific revolution on religion and poetry, Basil Willey makes the same point when he remarks, on the Royal Society's resolution (in Sprat's words) "to separate the knowledge of Nature from the colours of Rhetorick, the devices of Fancy, or the delightful deceit of Fables," that

> No clearer proclamation could be desired of the victory of the new world-picture, the fact-world, over the older worlds of traditional feeling. (213)

Willey cites especially the influence exerted on the literature and prose style of succceeding times of a Cartesian attitude toward language. Rene Descartes' "insistence upon sound and clear Reason, and clear and distinct ideas, and, in general, the mathematical lucidity of his spirit and writings, find their counterpart in the general set of that time towards prose and good sense, and in the reaction against the metaphysical tradition in poetry" (89). In his 1932 essay "Science and Language in England of the Mid-Seventeenth Century" (143-160) Jones argues that it is finally from the seventeenth-century experimentalists' regard of language with suspicion and distrust that our modern stylistic litany has issued:

> There should be little figurative language, especially metaphors, which falsely describe

> actions and things. There should be no verbal superfluity, but rather an economy of words sufficient to match exactly the phenomenon. Words should be the plainest possible, with intelligible, clear, and unequivocal meanings, preferably common words which are closer to material realities. There should be no emphasis upon or interest in the mode of expression for its own sake. Rhetorical ornaments and sheer delight in language represent a pernicious misplacing of emphasis, and in the end destroy the solid and fruitful elements in knowledge. (157)

A number of other writers over the past 50 years, beside R. F. Jones and Robert Adolph, have expressed their belief in the major influence of a scientific utilitarianism in the shaping of modern prose, including S. Michael Halloran, Merrill D. Whitburn, and Richard A. Lanham.[50] The work of Halloran and Whitburn on prose style addresses the latest development in the evolution of a scientific style of discourse, a development going

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[50] See for instance Lanham's (1974) discussion of "poetic prose," where he writes that

> No fundamental difference separates fictional from nonfictional prose, just as none divides prose and poetry. Any attitude, or combination of attitudes, may inform either pair, although perhaps the scientific attitude most often informs nonfictional prose. (96, emphasis added)

beyond the taking root of a strong faith in its proposed standard of "correctness" to its widespread institutionalization. The authors illustrate this development in business, industry, and government:

> Former President Carter's executive order 12044 mandated that regulations be `as simple and clear as possible', and the Office of Management and Budget is currently striving to carry out his order by promoting plain English in federal agencies. HR 6410, a bill that calls for sweeping revision of the writing done by both the federal government and organizations dealing with the federal government, was recently signed into law. Laws calling for the use of plain language are on the books or under consideration in fully half the states. Banks are simplifying their loan forms, insurance companies their policies, and realtors their contracts. Industries like IBM, Bell Laboratories, United Technologies, Sunstrand Aviation, and General Motors are making major commitments to promote plain language in their publications. (1982, 58)[51]

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[51] The authors argue that "the growing concern for plain and effective communication in technology, business, and public affairs should be met by a reaffirmation of human judgment as superior to any quantitative methodology" (71). Such a reaffirmation would in their view entail our adherence to Cicero's "symphonic" notion of style rather than to some generic "all-purpose"

This progressive regularization of plain English, especially in government and private business, is noted also by Janice C. Redish (1985) in her overview of the development in the 1970s and progress in the 1980s of "The Plain English Movement."[52] The latter is defined by Redish as "the effort to simplify the language in legal, government, business, and academic documents" (125). "Plain English," she writes,

> means writing that is straightforward, that reads as if it were spoken. It means writing that is unadorned with archaic, multisyllabic words and majestic turns of phrase that even educated readers cannot understand. Plain English is

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stylistic ideal admitting the current bias for a depersonalized plainness. While the current plain style movement in government and business may be a different kind of plain style than that promulgated by the the modern scientists, Halloran and Whitburn do point out that researchers and communicators of our time, "in attempting to make style amenable to mathematical treatment, are taking fundamental steps similar to those taken by Newton and other scientific revolutionaries of the seventeenth century." Further, terms like "plain language" and "plain English, they note, "echo both the seventeenth-century term `plain style' . . . and the much older notion of a plain style found in classical rhetorical theory. We believe that recent thinking about plain language is rooted in the same simplistic positivism as seventeenth-century views on the plain style" (my emphasis).

[52] Unlike Halloran and Whitburn, who identify the plain style with the rise of modern science, Redish does not address at all the question of intellectual origin of the plain style. See also Jacqueline M. Dorney's ERIC/RCS report on "The Plain English Movement" (1988), which also focusses on plain language in government and business, but alludes as well to the connection with technical scientific writing.

> clear, direct, and simple; but good plain English has both clarity and grace (to borrow the title of Joseph Williams' excellent new English textbook). (125)

While the authors just quoted all recognize the intense pressure in our society for plain discourse, they are divided on their view of that pressure. Halloran and Whitburn are concerned with maintaining a Ciceronian balance in stylistic character, a balance that preserves the human, individualistic element of discourse; Redish's emphasis, on the other hand, is on utility, on language as a conveyor of information.[53]

The evolution of a scientific prose style tells the story of an ideological and attitudinal clash over the proper limits (Sprat's "right practice") in languaging behavior. In using a phrase like "languaging behavior," I do not mean to reduce the problem to sociobiology. Richard Lanham risks doing this, I believe, in his proposal of a "post-Darwinian humanism" which relies on putative genetic predispositions in language behavior--along the intentional vectors of play, game, and purpose--

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[53] Parallel and closely associated with Redish's defense of plain English, but applied in a wider context, is the empirical calculation of such notions as "maximal readability" (Hirsch, 1977) and "syntactic fluency" (Mellon, 1969). There is of course a "counter-movement," calling for the reaffirmation of a personal style; beside Halloran and Whitburn, one may include in this group such writers as George Kennedy, Ken Macrorie, and Richard Lanham.

which regulate a human "biogrammar."[54] Lanham subscribes to a Wilsonian sociobiolgy that regards the use of language (stylistic orientation included) ethologically, as having evolved in a natural phylogenetic sense.[55] Such a perspective, he argues, should prove useful in the forging of an urgently needed "post-Darwinian synthesis" which,

> by giving us a new way to think about human behavior, also gives us a new way to think about rhetoric, about literature, and about their relationship, as that works itself out in the university curriculum. These three worlds--composition, literature, and humanist curriculum

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[54] A more recent example of this attempted biologization of rhetoric, or synthesis of rhetoric and biology, is the discussion by Winterowd (1986, 11-24) of a "gene-scene dialectic," which, while more thorough and provocative in its scientific detail than Lanham's proposed synthesis, is certainly no more conclusive, except for his point about the obvious dependence of language on certain neurophysiological processes.

[55] On sociobiology, the study of the genetic basis of organismic (including human) behavior, see E. O. Wilson's Sociobiology: The New Synthesis (1975) and his popular work on sociobiologic theory On Human Nature (1978). Wilson makes many references to human language, the evolution of which he views as adaptive in the Darwinian sense. Sociobiologists have been severely criticized by biologists, philosophers, and others who view them as biological determinists (in their neglect of environmental influences on behavior). Wilson begins his final and controversial chapter of Sociobiology--titled "Man: From Sociobiology to Sociology"--with the proposition that the social sciences and the humanities (including literature) be viewed as specialized branches of biology, as "the research protocols of human ethology" (547). Ethology is the study of animal behavior in its natural habitats.

> --are being revitalized by the same evolutionary theory of behavior, and that revolution provides, finally, the central means of relating them. (1983, x)

My own use of the word "evolution" in this chapter's title differs from Lanham's use in that it does not presuppose the influence of a deterministic ethology, and refers instead to the historical development, in the competitive marketplace of ideas, of our culture's attitude toward style and the uses of language.

It is in just this context of stylistic attitude, minus the behavioral biology framework, that Lanham views the conflict over style in Style: An Anti-Textbook (1974).[56] The traditional Ciceronian tri-partite, high-middle-low division of style is inadequate, Lanham first asserts, because its great vagueness makes it

> nearly always applicable--especially so if you redefine it thoroughly, either morally or affectively. You can even adapt it to the dictates of clarity and scientific prose. The high style becomes bad, the middle good, and the low `colloquial'. . . . Because [the tripartite division] renders comparison invidious, it

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[56] This work was published one year prior to the appearance of Edward O. Wilson's controversial text, Sociobiology: The New Synthesis, which ignited a new form of the familiar "nature versus nurture" debate.

> introduces the dispute that invidious comparison inevitably brings. It cannot just describe, it must evaluate. Which purposes are best? Which subjects most serious? Who, what, most moral? More than this, it has repeatedly proved itself tone-deaf. It can tell you what was said and explain why it was said that way, but it seldom reveals the spirit in which it was said. It defines badly the kind of agreement struck between writer and reader. It forces us, finally, to take an attitude toward style, whether the attitude be formal (diction, syntax, density of figures), moral (as with Frye's definition), or scientific. (46-47, emphasis original)

What Lanham then proposes is a new, bi-partite basis for characterizing style, one that does not carry preconceived attitudes but aims instead to measure the psychological variable of "stylistic self-consciousness," asking:

> To what degree does a writer acknowledge his style as a style? To what degree are we to feel the style as such? To what degree, that is, does the style realize itself as opaque, as--the enemy of clarity--a style to be looked at rather than through? (47, emphases original)

In this at-through stylistic duality (or spectrum of

options) one will again recognize the res versus verba quandary of the pivotal period in intellectual history encompassing the educational reforms of Ramus and Bacon--but in a supposedly neutral context, one which does not fall prey to biased attitudinizing. For Lanham, the fundamental consideration regarding style requires only a stylistic judgement:

> How should we attend to or "take" the style? Does it diminish into insignificance on the right or does it move left, growing so large in our consciousness as to become the subject? (54)

Thus, the evolution of a scientific prose style may be viewed as a struggle for recognition and dominance of an empiricist attitude toward style which, in Lanham's model, draws attention to its subject--material/factual reality--to a degree which in effect seeks to disallow style (Ramist rhetoric) as an important element in scientific discourse and, if the Baconian loyalists had their way, in popular discourse generally. This aspect of the evolution of a scientific prose style--i.e., its competitive struggle with what might be called, for lack of more precise language, a humanistic style--is of course at the center of our story. It is symbolic of the deeper problem which C. P. Snow embodied in his famous metaphor of the two cultures. Essentially, the conflict is rooted in differences in world-view which have have led, not to a

working synthesis, but instead to a struggle for intellectual sovereignty among the competing pictures of reality. Consequently, an artificial schism (something like a corpus callosum) has been perpetuated in our intellectual tradition, with the competing parties emphasizing their special value practically to the point of caricature. (Yet, paradoxically, as will be seen in the following chapters, there has always existed between rhetoric and the new science a vital complementarity.)

I would like to reiterate here, as a final note, that my chief aim in this chapter has been two-fold: to argue for a Ramus-Bacon-Royal Society connection in the genesis and evolution of a scientific plain style, and to suggest that the change in stylistic orientation between Bacon's and Sprat's time has survived through the centuries to form the basis for the current premium placed on plain discourse, not only in the spheres of government and business, but also in the sphere of education (i.e., writing instruction). It is worth noting, for instance, that in the eighteenth century the battle with regard to manner versus matter in discourse is reflected in the opposing sides taken by the perspicuitists, represented by such works as George Campbell's 1776 The Philosophy of Composition and Hugh Blair's 1783 Lectures on Rhetoric and Belles Lettres, and the elocutionists, whose representative works include John Holmes' 1739 The Art of

Rhetoric Made Easy and John Sterling's 1788 A System of Rhetorick in a Method Entirely New. In his discussion of these two movements, Winterowd (1968) writes that Holmes, like other elocutionists, "made a clear distinction between logic and rhetoric, the same kind of division that Ramus made two hundred years earlier. To the elocutionists, manner was virtually the all" (59). For Winterowd, the rationalistic attitude toward discourse expressed in the writings of Blair and Campbell are the culmination of the plainness ethic voiced by Sprat, Wilkins, and the Royal Society in the third quarter of the seventeeth century. "Together," continues Winterowd,

> the Aristotelianism of the rationalists and the Ciceronianism of the elocutionists constituted the scene from which a modern rhetoric might emerge. Longinus had provided the doctrine of the sublime, the viaticum whereby matter and manner could be separated. Rationalism posited psychological theories that gave philosophical credence of the doctrine of perspicuity and the plain style. And the elocutionists brought a kind of rhetoric to the masses--a kind of rhetoric that concerned itself largely with the `flowers' of discourse. (74-75)

In the neoclassical age of the eighteenth century, he suggests, are clearly defined the rhetorical problems of

our age, an age which still awaits the synthesis of a new rhetoric, to be molded in part from the developing knowledge in linguistics and psycholinguistics.

There are comforting indications that an important change has been occurring during the past 30 years in the meaning of the word "conflict" in reference to the relationship between the humanistic-rhetorical and scientific traditions. The shift in meaning is from the customary sense of combativeness to a positive, post-modern connotation of an ongoing dialectical exchange that is constructive.[57] In this emergent intellectual climate, stylistic orientation is a matter of conscious personal and circumstantial choice rather than a pressure to conform to some universal ideal of plainness. The complementarities and reciprocities of humanistic and scientific styles, rather than their structural-intentional differences, becomes the focus. Such a change

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[57] See Herbert Dingle (1955), who points out that the destructive side of the friction between art and science has been ameliorated, if not totally dissipated, by the recognition in our century of more than one order of truth and beauty. (Hence, one might add, I. A. Richards' later use of the plural forms "poetries and sciences.") This new intellectual climate is represented by such dialogues as those imagined by Bronowski (1965) and Schlossberg (1973), mentioned earlier. A salient example of the new attitude from my college experience (circa 1981) is a Literature and Psychology course, team-taught by a literary critic and an experimental psychologist whose pedagogical style was to draw the class into their term-long dialogue, aiming to weave together into a working historical unity the scientific and literary world-pictures.

means, for instance, the recognition that the style of scientific prose is in actuality not limited to that demanded by the reportage of laboratory results or by technical theoretical discussions. Thus, today we introduce our freshman composition and scientific writing students to the stylistic diversity exhibited by the popular works of scientists,[58] and to the literary works of those scientists who have allowed their science the linguistic freedom of excursions into the world of fiction. In the broader picture, the fiction and poetry written by scientists forms part of the perennial thematic presence of science in the fiction, poetry, and drama of western culture generally,[59] to which considerations, and their illustration, I return in Chapters Two and Three.

To reiterate, then, as I proceed to a discussion of the rhetorical range of scientific writing, there are three dimensions of the evolution of scientific writing which are separable for individual consideration. First--the chief concern of this chapter--is the stylistic dimension, with respect to which I have explored the possibility of a Ramus-Bacon connection in the rise of a scientific plain style; it is this modern plain style, I

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[58] See, e.g., the anthologies by Bowen and Mazzeo (1979) and Lynch and Swanzey (1981).

[59] See, e.g., Crum (1931), Nicolson (1956), Franklin (1966), Jones (1966), Heath-Stubbs and Salman (1984), Gordon (1985), and Digby and Brier (1985).

have also suggested, which is intimately associated with the plain English movement of the past 15 years. The second major aspect of the evolution of scientific writing becomes evident when the definition of scientific writing is broadened to include imaginative literature--fiction, poetry, and drama--involving science as a central concern. These first two aspects of the evolution of scientific writing--its development as a style and as a part of the literary tradition--place writing associated with science in its proper rhetorical context. The third aspect of the evolution of scientific writing involves its emergence, especially since the 1960s, as a pedagogical specialization in the college curriculum (see Verbit, 1983). This last topic is addressed in Chapter Three, where I discuss the importance of the study of scientific writing in relation to liberal education; that chapter argues for the important role of English studies, whose special focus is on language, in exploring and imparting a clear and balanced sense of the historical struggle between the humanistic and scientific traditions, and of their complementary relations in the context of learning and rhetoric.

CHAPTER II

THE RHETORICAL RANGE AND DIVERSITY OF SCIENTISTS AS WRITERS

Scientists who view their writing in literary or rhetorical terms are exceptions to the norm. In a short essay addressing the question "What is good scientific writing?", written for a peer audience of medical writers, physician Charles G. Roland observes that as a consequence of the dissociation of science from the humanities

> physicians [and by implication laboratory scientists] seem to think that scientific writing is not a literary form; the very word `literary' frightens many, who believe that science is objective while literature is subjective. They pursue this belief to its questionably logical conclusion by supposing that science is only objective, and that therefore it must be antiliterary. (1971, 3-4, emphasis original)

What Roland means by "literary," in the context of scientific writing, is "the ability to write clearly, unequivocally, concisely, and pleasingly" (3). His

conception of good scientific writing boils down to the familiar strictures of the plain style, with the notable addition of "pleasingly." Though Roland does not explain his use of "pleasingly" in connection with what he means by "literary," it seems clear that by good scientific writing he also means good scientific rhetoric. Thus, were it not for the relative inaccessibility to him (as a scientist) of the concept of rhetorical art, he might have said that it is wrong as well to think of science, and of scientific writing, as anti- or non-rhetorical.[60]

The belief that science and rhetoric (as a humanistic discipline) are "opposites"--a belief indirectly encouraged by Snow's Rede Lecture--suggests the equally flawed view that these two intellectual arts are totally separable and mutually exclusive ways of learning and thinking. In a review of Dominick LaCapra's History and Criticism (Ithaca: Cornell UP, 1985), Steven Weiland notes how, in drawing attention to the rhetorical nature of historiography, LaCapra points the way toward a parallel awakening with respect to the way science and rhetoric are perceived to relate to one another:

> It is as false, LaCapra insists, to hold science and rhetoric to be opposites as it is to

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[60] In the broadest view of rhetoric as the writer's manipulation of language to achieve an intended effect on a particular audience, even the aim to "please" stylistically is a rhetorical strategy.

> claim that a plain style is the only acceptable one for truth-seeking in prose. To be scientific and anti-rhetoric, he says, amounts to `a self-denying quest for a certain rhetoric, a rhetoric unadorned by figures, unmoved by emotion, unclouded by images, and universalistic in its conceptual or mathematical scope' (42). (1987, 822)

In this chapter I develop the alternative view that, far from being isolable from rhetoric, scientific writing has a rhetorical framework of its own, one that is contiguous with the classical rhetorical tradition in several fundamental ways. There are a number of studies in the "rhetoric of science" literature which show for instance that, even in their technical reports, scientists engage in argumentation (versus merely reporting), project a rhetorical ethos, and use metaphoric language. Though my focus initially is on technical scientific writing, I define "scientific writing" broadly enough to include other kinds of writing by scientists, such as science popularization and scientific fiction, which I discuss later in the chapter.[61] Beyond the understanding that they must "write up" their experimental findings, and

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[61] One aspect of scientific rhetoric which I do not discuss here, but which is important to note, is the use of persuasive strategies in public deliberation--grant proposals, convention papers, and public debate (Wander, 1976).

submit them for publication in a standardized format--i.e., introduction, methods and materials, results, and discussion--scientists are not inclined to discuss amongst themselves such matters as the style, personality, or the persuasive power of their research reports. Their attitude is that the facts, accurately and fully presented, speak for themselves. Yet, as Susanne Langer (1957) noted, even a "fact" is not so much found as it is made--it is "an intellectually formulated event, whether the formulation be performed by a process of sheer vision, verbal interpretation, or practical response" (269, emphasis original). In the context of Langer's definition, a fact is essentially an argument for the view of reality constructed by the fact-maker.

In The Manufacture of Knowledge, Karin D. Knorr-Cetina argues that a scientific research "report" is in actuality a rhetorically decontextualized artifact which, through a selection process involving what is told and how it is told, actually presents a "disfigured" or "perverted" version of the full social--and rhetorical--context of laboratory activity. What is not visible in the written product of the research process is the web of more subjective social interactions--the oral rhetoric--among the group of scientists who participate in various capacities (e.g., as advisors, technical assistants, and principal researchers) as the experimental work moves

closer to its final written form. She demonstrates how, in preparing technical reports, scientists use a number of "rhetorical strategies for objectification," including paragraph organization, choice of vocabulary, grammatical structure (such as use of passive voice and regal we), "redoubling" (offering both sides of an argument), and avoidance of explicit value statements.

As a social-anthropological study of the connection between what happens in the laboratory and how that process is rhetorically re-contextualized or transformed in its written representation, Knorr-Cetina's analysis of a specific scientific paper (one of the few such studies available) is remarkable for its completeness and detail.[62] The paper she dissects deals with an alternative method for protein precipitation for use in protein recovery, and is titled "Potato Protein Concentrates: The Influence of Various Methods of Recovery Upon Yield, Compositional and Functional

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[62] See Chapter 5 of her book, "The Scientist as Literary Reasoner, Or the Transformation of Laboratory Reason," 94-135. The unique aspect of her study is the complete access she had--while the experimental work was in progress--to both the scientists involved and the many drafts (16 in all) which the paper she analyzes underwent up to its publication. In her presentation, Knorr-Cetina juxtaposes interview responses of the principal scientist involved, a protein chemist, with the many specific changes made in his report as its final draft emerged.

Characteristics."[63] In comparing the original draft with the published version of the paper, Knorr-Cetina identifies three major strategies of modification: deletion of particular statements, change in modality of certain assertions, and reshuffling of the original statements. These changes are especially evident and important in the paper's Introduction, for, as Knorr-Cetina shows, it is here that laboratory reasoning is recast, "purged of personal interests and situational contingencies," by the rhetorical demands of writing for publication; changes made in later sections of the paper are determined in turn by the new rhetorical framework constructed in the Introduction.[64]

In the case of the "Potato" paper, the published version of its Introduction "dissimulates the dramatic emphasis and straightforwardness found in version 1 [through] . . . a series of modifications which run counter to the rhetoric of the original presentation" (102). Many specific examples are provided by Knorr-

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[63] Knorr-Cetina makes available in Appendices to her book (154-172) the entire first draft and the final, published version of the paper, which appeared in 1978.

[64] Knorr-Cetina shares Medawar's view that scientists are "always telling stories," and asserts that the Introduction of a scientific paper "is complete with respect to such conventional elements of literary structure as tension and resolution, identification of good and bad, and organized development of action. Susequent sections function more as appendices to this structure than as the unfolding of a dramatic structure" (100).

Cetina of deletions, changes in modality, and rearrangements of statements to demonstrate the kind of rhetorical transformation she postulates. Deletions of statements typically are of two kinds,

> either arguments which essentially reinforced a certain point, or assertions considered `weak' or `dangerous' . . . For example, four of the fourteen statements eliminated from the first-version text accentuated the negative value of the prevailing protein recovery method by commenting on its disadvantages or the `advantages' of $FeCl_3$ as a `major' alternative. Another group of eliminated statements reinforced a previous point, such as the phrase, `if the remaining 70-80% could be converted into nutrients . . .' which immediately followed the phrase `According to Kramer and Krull (1977) only 20-30% of the vegetable plants are utilized directly for human consumption . . .'. The former statement was deleted because it was `obvious'. Yet the latter statement did not meet with approval either. It was later deleted as a `dangerous' claim which was expected to generate opposition and disbelief. (102)

A similar weakening or "softening" of the dramatic character of the Introduction is effected by the other two

major types of changes. The modality of certain statements was changed "from the necessary to the possible" and generally from strongly to weakly made assertions:

> Instead of saying that something `is' the case, we find that `it has been suggested as possible'; instead of `should', we find `could'. Expressions like `mainly' are watered down to `usually' or `commonly', and the `good' solubility of PPC becomes merely `enhanced'. The scientists either hold back claims, or couch them in terms which denote hesitation and doubt. (102)

The reshuffling of statements in the original Introduction over subsequent drafts leads, in Knorr-Cetina's view, to a loss of clarity and straightforwardness; the original Introduction had a paragraph structure moving from the general to specific, while in the published version of the Introduction the paragraph organization is "nested" (i.e., previous topics are resumed later). Consequently,

> the final Introduction proceeds by a spiral-like hedging in on the purpose it gives to the study. This hedging in is accentuated by the softened surface of propositions produced by [modality changes], with the result that any dramatic climax is diffused and difficult to identify. (102-103)

Caution must be exercised in generalizing from what happens, rhetorically speaking, in the writing up of one particular paper to any kind of statement which is descriptive of the scientific writing process as a whole. What does seem generalizable from Knorr-Cetina's study is that the writing of a scientific paper is a process that involves, no less than in other kinds of writing, the making of rhetorical choices--as in the deletion of value judgments, the wording of assertions, or the relative position of particular statements; in other words, scientists as writers are also rhetors.[65] In the sense used by Halloran and Whitburn (1982), technical scientific writing is a rhetorical orchestration shaped by specific motives and for specific effects on the reader.

Viewing the technical writing of scientists in a rhetorical light in no sense implies an act of deliberate

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[65] That scientists are rhetors in the act of composing laboratory reports does not presuppose that all scientific activity is fundamentally rhetorical--any more than, analogously, literary/rhetorical studies are fundamentally scientific simply because, say, language abilities are in part biologically-based (in the sense that humans inherit neural language centers), or because linguists like Noam Chomsky have developed empirical models of language structure-function relationships, or even because one may be able to describe objectively and systematically, as Northrop Frye has asserted, how literature "works." Rhetoric has its undeniable place in science just as, reciprocally, science certainly has its place in literature (e.g., thematically, metaphorically). The delineation of these reciprocal relationships is a large part of the formidable challenge of arriving at a deeper understanding of the relative role of science and literary creativity in human learning and maturation.

deception or misrepresentation by scientists in the communication of their research.[66] Herbert W. Simons (1980) rightly criticizes the frequent appearance in the rhetoric of science literature of the image of the scientist as a "rhetor in disguise,"

> one who falsely pretends to the status of nonrhetor and thereby renders his rhetoric deceptive; one, moreover, who is not above engaging in such allegedly sophistic practices as masking self-serving motives behind a vocabulary of legitimizing motives or subtly promoting partisan values in the guise of being informative. (115)

The problem, as Simons points out, is with the words "in disguise." Why should scientific rhetors be any more (or less) liable to misuse rhetorical art than any other classification of rhetor one may choose to define? What is revealed and objectified by detailed analyses, like Knorr-Cetina's, of specific technical reports is a

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[66] Though it is interesting that Medawar (1982) states that it is practically impossible to gain an insight into how scientific methodology operates by simply reading journal papers since they "not merely conceal but actively misrepresent the reasoning that goes into the work they describe" (132). On this point, he cites Karl Popper's "Science: Problems, Aims, Responsibilities" (Federation Proceedings, 22: 961-972, 1963) and his own broadcast "Is the Scientific Paper a Fraud?" (Listener, September 1963). The best way to understand what scientists do in the laboratory, Medawar suggests, is by listening to the laboratory oracy itself (as Knorr-Cetina has done).

way of communicating within one specialized language community.

The observation of a characteristic manner of handling the language by scientists, a manner grounded in a traditional value system of its own, suggests another aspect of the rhetorical nature of technical scientific writing--namely, that such writing projects a distinctive persona or ethos.[67] How an ethos is projected in

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[67] Although "persona" is a literary and "ethos" a rhetorical term, their senses merge in that both terms entail choices with respect to human values, both deal with character and the motives of human conduct. See Paul Newell Campbell (1967), who argues that scientists construct personae which are a reflection of the attitudes, points of view, and values of the writer. For Campbell, the persona is more than merely a literary product; it is a personality that is created in the act of communication. "What is true of the actor is also true of our language," he writes,

> for on one level, our language, our discourse, is a dramatic, a presentational form that excludes the negative. At bottom, our discourse is always poetic and rhetorical, always formally expressive, attitudinal, and hortatory; i.e., we are always symbolizing for the joy of symbolizing, and we are always taking points of view, and expressing attitides, never taking no-point-of-view or expressing nonattitudes. Thus, our discourse, scientific or otherwise, can only display those attitudes we do, in fact, demonstrate, for on the level on which to discourse is to perform, to enact, we can only enact those attitudes, beliefs, biases, opinions that constitute the personae of such discourse. (404)

Campbell's performative view of discourse limits the meaning of "plainness" in scientific writing. While it poses no difficulty to the notion of scientific writing as a style of prose that is straightforward and simple in its phrasing, and that draws greater attention to its subject than to its words, it rejects the possibility that scientists can write in a manner that totally excludes the personal, sentient element of human communication.

technical scientific writing is illustrated by S. Michael Halloran's (1984) case study of the 1953 Nature article, titled "A Structure for Deoxyribose Nucleic Acid," in which James Watson and Francis Crick proposed their famous "double helix" genetic model. Halloran believes that, both argumentatively and stylistically, the Watson-Crick paper "articulates a recognizable public persona . . . a particular image of the scientist speaking, within a broader set of more vague and general norms that apply to all scientific discourse" (75, emphasis original).[68]

Argumentatively, Watson and Crick support their proposed DNA structure in three major ways, ways which serve not merely to present the experimental data, Halloran claims, but to offer, alongside the proposed genetic model, "a model of the scientist, of how he ought

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[68] Like Campbell (1975), Simons (1978) and others, Halloran sees these rhetorical norms--which together comprise a scientific ethos--in terms of Kuhnian paradigms. The kinds of questions a Kuhnian rhetorician should ask, according to Simons, includes the following:

> How in particular do paradigms gain acceptance? By what strategems and through what channels are theoretical innovations diffused? In the absence of fully formalized rules, what role is played by exemplars and by enthymematic appeals? How is the language of one paradigm translated into the language of another? (129)

Halloran's study of the Watson-Crick paper suggests preliminary, working answers to such questions. As to the first of these questions, for instance, Halloran believes that, while it is undeniably the technical particulars of the double-helix model which have ultimately determined its importance, the ethical-rhetorical aspect of Watson and Crick's work, its ethos, "contributed to the speed with which their model of DNA gained prominence as a theory" (78).

to hold ideas and present them to his peers" (78). The chief argument used by Watson and Crick--an implicit appeal to the theoretical elegance of the base-pairing mechanism holding the two DNA helices together--"is in effect an enthymeme whose missing premise is a scientific topos so basic and powerful that it would be gauche in the extreme to state it openly in a technical paper" (73).[69] The second major argument offered by Watson and Crick, relating to the observed base-pair ratios in their DNA model, is also implicitly presented and left for the reader to make the connection with the first (base-pairing mechanism) argument; this constitutes for Halloran "another enthymeme resting on the topos of explanatory power." The third and final argument--which points out the inconsistency of their proposed structure with available experimental data--is the only explicitly stated argument; however, like the other two arguments, it is carefully qualified and understated. Thus, rhetorically, the paper's manner of argumentation communicates, in Halloran's view, "a sense of supreme confidence . . . [and] the arguments in support of the model are assumed to be so persuasive that they need no

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[69] Halloran cites H. F. Judson's observation, in The Eighth Day of Creation: Makers of the Revolution in Biology (New York: Simon and Schuster, 1979, 196-198), that Watson's appeal to the reader's sense of theoretical elegance is made explicit in The Double Helix: "a structure this pretty just had to exist."

bolstering or emphasis" (74).

Stylistically, Halloran notes that the salient feature of the paper is its consciously contrived "genteel tone," especially when compared to the arrogant attitude surrounding the discovery that is expressed in Watson's own account in The Double Helix (1968).[70] "If we can believe The Double Helix," writes Halloran, "the genteel style of Watson and Crick's first published paper reflects a rhetorical persona, perhaps fabricated with a bit of intentional, tongue-in-cheek irony; in the flesh they were obstreperous and irreverent" (74). Halloran notes that the authors' self-consciously genteel style, combined with their avoidance of the conventional passive style, invests their prose with a highly personal tone that is unusual in technical scientific writing, and that this personal dimension--this individual ethos--evident in their paper

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[70] See the edition by Gunther S. Stent (New York: W. W. Norton, 1980), which includes useful commentary and reviews. The diction of qualification and understatement evident in the Watson-Crick paper contrasts sharply with Watson's own account of the discovery, Halloran points out, which shows that he and Crick were astonished and jubilant at the great blunder (involving elementary chemical principles) that they found in Linus Pauling's proposed DNA model. Examples given by Halloran of the genteel wording used in the Watson-Crick paper are such phrases as "We wish to suggest a structure . . . ," "in our opinion," "we believe," "it is not clear," and "appear to be." Finally, for Halloran, in the famous concluding sentence of the paper "the genteel style becomes a transparent burlesque . . . One can almost feel the elbow in one's ribs: `It has not escaped our notice', Watson and Crick wrote, `that the specific pairing we have postulated suggests a possible copying mechanism for the genetic material'."

holds important implications for rhetorical studies of scientific discourse: namely, that

> except at the most general level, it may be misleading to speak of the rhetoric of science . . . that other particular cases of scientific rhetoric will exhibit their own peculiarities. A detailed understanding of the rhetoric of science will have to include some sense of the permissible range of variation. To achieve this we need a body of critical literature on particular cases of scientific discourse. (80-81)[71]

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[71] Halloran believes that what is needed is a critical approach which Edwin Black (1980) calls emic: "criticism that begins with the particular instance and aims toward the development of theories comprehending more general principles that operate across larger bodies of discourse" (81). Halloran's suggestion that it is wrong to speak of the rhetoric of science is complemented by Medawar's (1967) advise against believing in such a thing as the scientist:

> Scientists are people of very dissimilar temperaments doing different things in very different ways. Among scientists are collectors, classifiers and compulsive tidiers-up; many are detectives by temperament and many are explorers; some are artists and others artisans. There are poet-scientists and philosopher-scientists and even a few mystics. What sort of mind or temperament can all these people be supposed to have in common? Obligative scientists must be very rare, and most people who are in fact scientists could easily have been something else instead. (1967, 132, emphasis original)

Though it is possible and useful to delineate certain aims and values shared by scientists as a community, as Jacob Bronowski attempted to do, scientists are still individual human beings whose individual perculiarities find expression, in Halloran's view, along with the technical

Halloran seems to be trying to reconcile the paradigmatic view of scientific activity with the inviduality and diversity of human expression. Thus, while he believes that the Watson-Crick ethos has come to serve as a paradigm for other scientists, he also recognizes (and encourages the development of) the personal and unique aspect of scientists as writers.

To illustrate the stylistic variation in scientific writing--and the differences in what perceives as the old and new paradigms--Halloran compares the Watson-Crick paper with the earlier article by Oswald Avery et al. on the crucial role of DNA in heredity[72]; as a rhetorically sophisticated construct--i.e. as a confident, yet deliberately understated, attention-getting introduction to the still-to-come details of what they well knew to be a great discovery--the 1953 paper

> presumes an understanding of science as a human community in which neither facts nor ideas speak

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side of their scientific writing. Relevant to Black's emic approach are the numerous case studies of the oral rhetoric essential to laboratory research, which supplement analyses of the written texts produced by scientists; see for instance Greg Myers' "Writing Research and the Sociology of Scientific Knowledge: A Review of Three New Books," College English, 48: 595-610, October 1986. (Knorr-Cetina's study, cited earlier, does combine analysis of both oral and written laboratory rhetoric.)

[72] Oswald T. Avery, Colin M. Macleod, and Maclyn McCarty, "Studies on the Chemical Nature of the Substance Inducing Transformation of Pneumococcal Types," Journal of Experimental Medicine, 79: 137-158, 1944.

> for themselves, and the attention of an audience must be courted. By contrast, Avery and his colleagues present their work in a single technical paper structured in a reportorial pattern which implies that facts do speak for themselves. Their strategy seems to presume that the work of the scientist is simply to give oneself up to the facts. Avery speaks from within an essentially positivisitic, pre-Kuhnian view of science, Watson and Crick from within what Frederick Suppe [in The Structure of Scientific Theories] calls a Weltanschauungen view. They recognize that a discipline includes tacit assumptions about what is and what is not a legitimate question, and that in order to gain a hearing for a new theory, one may have to suggest what use the theory might have, what new questions it might pose and answer, what new lines of research it might open up. (77-78)

The contrast between the Avery et al. and Watson-Crick papers, I would also suggest, is a consequence of the tacit understanding and acceptance by the later authors of the importance of rhetorical art in the shaping of scientific discourse.

Beside engaging in rhetorical argumentation (vs. merely reporting data) and projecting a scientific ethos

in their discourse, scientists as writers rely on another aspect of rhetorical art in developing and communicating scientific concepts: figurative language. As with the argumentative and ethical aspects of scientific discourse, the use by scientists of figurative language shows that technical scientific communication goes beyond the presentation of purely objective information. "No synthesis could ever be achieved, no models postulated, no paradigms established," write Halloran and Bradford (1984),

> if science relied wholly upon `careful observation' for its theories. Model-building requires an inductive leap; carefully recorded examples must be synthesized into a logical premise, and then be further verified and expanded by traditional scientific method. For this, science must exploit the power of metaphor; it must shape its expectations, choose its experiments, and interpret its data in a realm of thought outside the literal world. (183)

It is true that scientists traditionally have rejected the use of figurative and metaphoric expression, as exemplified by the vituperations of Thomas Sprat. However, in his discussion of the attitude of contemporary scientists toward the use of metaphor in theories, Robert R. Hoffman (1980) makes two important points. First,

scientists are not in complete agreement over the place of metaphoric expression in science. Physicist Rene Duhem and computer scientist M. A. Arbib are examples of critical attitudes--pointing to the ambiguity or open-endedness of metaphors--while the nineteenth century physicists James Clerk Maxwell and Michael Faraday acknowledged and encouraged the use of metaphor in science. Maxwell believed that metaphors are not only "legitimate products of science, but capable of generating science in turn."[73]

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[73] Quoted by Hoffman from Maxwell's "Address to the mathematical and physical sections of the British Association," British Association Report, 1870, II; reprinted in The Scientific Papers of J. C. Maxwell, II, Ed. W. D. Niven (Cambridge: Cambridge UP, 1890), 226. Hoffman also quotes from an 1879 letter Maxwell sent to William Thompson: "I never sailed through a plate of meerschaum on a molecule, so that I do not know whether the passage is like the Forth & Clyde or like the Caledonian Canal but I should not expect to have many long reaches, but rather plenty of locks and sluices so that it would not be very much like a tube but more like a cullender." Other relevant sources cited by Hoffman include Duhem's 1906 The Aim and Structure of Physical Theory (Trans. P. P. Weiner, Princeton: Princeton UP, 1954) and Arbib's The Metaphorical Brain (New York: Wiley, 1972). Duhem and Arbib argue that metaphors are too limited and imprecise (and therefore misleading) to use in theory-building, and are appropriate only for pedagogical purposes. See also Turbayne (1962), who discusses the use of metaphor by Descartes and Newton and concludes that they were victimized by their metaphors,

> victimized because they presented the facts of one sort as if they belonged to another, but without awareness. They were engaged in sort-crossing. But because they did not know that they were, they confused their own peculiar sorting of the facts with the facts.It was as though, having found that wolf-properties were eminently suitable for illustrating man, they came to believe that he was indeed a wolf. (46)

Indeed, there are a number of important examples of the reliance on metaphor by scientists. Physicists may see the atom as a microcosmic solar system, biochemists use the "lock and key" analogy in referring to enzymatic activity, and computer scientists compare the human mind to computer function. Halloran and Bradford explore at some length the power in biology of the genetic "message" metaphor, a metaphor that in both popular and technical discussions of DNA "can add presence and life to an idea that is otherwise remote and lifeless. Those four [DNA] bases somehow take on a heightened reality when seen as letters in an alphabet used to spell out instructions to the machinery of the cell" (184). A whole vocabulary is created to support the metaphor. For lay audiences, and often in the technical periodic literature, the workings of DNA are represented by such words as coding, transmitting, transcribing, and translating of genetic "information."[74]

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[74] One of the authors' specific illustrations from popular works is the Time-Life Science Library volume by John Pfeiffer on The Cell [New York: Time Inc. 1964], in which the DNA code is referred to as "The Alphabet that Spells Life" and compared, in the great amount of information ("instructions") it holds, to volumes in an encyclopedia. Halloran and Bradford also cite the use in technical journals (e.g., Science, Nature, and The New England Journal of Medicine) of such words as expression, messenger, editing, and reading. See also the essay by Owsei Temkin on "Metaphors of Human Biology" (1949), in which the author develops the thesis that "metaphors have exercised considerable influence over the biologists' thought," with examples taken from the history of medicine.

For science itself, the message metaphor is not merely a metaphor, argue Halloran and Bradford, but a

> fundamental metaphor, a metaphor to think and work by. It has become basic to molecular biology's way of interpreting experience--so much so that it has set the agenda for much of the research done in that field since Watson and Crick's discovery of the double helix. One of the great questions that occupied biologists throughout the 1950s and into the sixties had to do with what we might call the morphology of the genetic code. The metaphorical basis of this work is perhaps most apparent in Crick's effort to devise what he called a `comma-free code', a morphological scheme in which the boundaries between meaningful units--`words'--on the DNA molecule would not have to be marked by discrete spacing elements--`commas'. His notion turned out to be mistaken, but what interests us here is his way of conceptualizing and expressing the problem. The experience of communication through language served as an organizing perspective on the working of DNA. (187)

Halloran and Bradford demonstrate how metaphorical thinking in scientific activity and technical discourse can serve as a powerful organizing force, as a vehicle for

further thought and model-building.[75] Moreover, according to E. Fred Carlisle (1980), who has compared extensively the discourses of literature and science, the function of models in science is practically identical to the function of literary metaphors, since "both models and metaphors build situations or construct an equivalent world or system that organizes a less well known, or a diverse, amorphous, reality and makes it intelligible" (46).[76]

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[75] The authors cite the parallel point made by George and Mark Johnson in Metaphors We Live By (Chicago: University of Chicago Press, 1980), and argue that scientific metaphors are similarly useful in lending coherence to experimental observation and theory development. See also Agnes Arber's essay "Analogy in the History of Science" (1944), in which the author points out the historical use of analogy among scientists not only in suggesting hypotheses, but in exposition as well. One of Arber's examples concerns Francis Galton's symbolic description (just prior to the rediscovery of Gregor Mendel's work) of "particulate inheritance," in which he uses an analogy from the construction industry. (Arber selects a lengthy passage from Galton's 1889 Natural Inheritance to make her point.)

[76] In suggesting that certain kinds of scientific models are really metaphors, Carlisle draws on such works as Max Black's Models and Metaphors (Ithaca: Cornell UP, 1962) and Mary Hesse's "The Explanatory Function of Metaphor," in Logic, Methodology, and Philosophy of Science, Ed. Y. Bar-Hillel (Amsterdam: North-Holland, 1965). Hesse asserts that "theoretical explanation in science is a metaphoric redescription of the domain of the explanandum." Other works cited by Carlisle which show the importance of metaphorical expression in science include Paul Ricoeur's The Rule of Metaphor (Toronto: University of Toronto Press, 1977) and W. H. L. Leatherdale's The Role of Analogy, Model and Metaphor in Science (New York: American Elsevier, 1974). Though Carlisle is interested in making a beginning toward developing a "poetics" or rhetoric of science, one major weakness of his study, when compared to the studies by Knorr-Cetina (1981) and Halloran and Bradford (1984) is the absence of specific applications to individual cases

In the foregoing discussion of technical scientific writing I challenge the notion, perpetuated historically by attitudinal biases within both the scientific and the literary communties, that technical scientific discourse and classical rhetoric have little, if anything, to do with one another.[77] It seems clear that science and its technical language operate within--not a rhetorical vacuum--but a rhetorical tradition with its own manner of argumentation, of explaining reality, of imagining and constructing worlds; one with its own ethos, and its own attitude toward language. Further, a rhetorical view of scientific writing permits the recognition that, beyond the sphere of the technical communication and its limited audience, scientists as a community have developed other--more personal and sometimes literary--outlets for sharing their knowledge, their ideas, and their world with society at large. They have developed a broader-based rhetoric, one that reaches out from the inner circles of the laboratory to the widest possible audiences. Whatever the

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of technical scientific writing. With regard to nineteenth century science, a number of studies have been published on the rhetorical dimension of the writings of Charles Darwin, particularly his use of evolutionary metaphors. (e.g., Campbell, 1970; Hyman, 1974).

[77] An example of the current prevalence of this attitude among rhetoricians is the omission in E. P. J. Corbett's Classical Rhetoric for the Modern Student of a rhetorical analysis of a scientific essay (either technical or popular), or even of scientific fiction, written by a laboratory scientist.

precise reasons may be, many scientists in this century have been willing to engage in self-scrutiny, to lay open their souls, to recognize that human values and moral responsibility are an integral part of scientific activity.[78] What this means, in the context of the subject of this chapter, is that scientists as writers are more than technical rhetors. The rhetoric of science extends into such traditional-humanistic forms as the popular essay, fiction, and poetry.[79] Therefore, a discussion of the rhetorical range and diversity of scientists as writers should include attention to these forms of scientific rhetoric. In the illustrations which follow, my aim is to show how the less technical rhetoric of scientists is continuous with their concerns in the

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[78] The substantial body of intimate, introspective, and creative works by contemporary scientists has surely been prompted in part by the the horrors of two world wars, with all the human loss to ever more innovative forms of psychological, chemical, and physical annihilation that scientific advances, together with the particular cultural mindset, have made possible; further causes for scientists to reach the widest possible audiences as they themselves reflect upon their work are such spectres as a nuclear holocaust, runaway environmental pollution, the population "timebomb," genetic engineering, and the dehumanization of the workplace (which many fear will be the legacy of the computer and robotics revolutions) of the post-industrial age.

[79] In the third chapter, on pedagogical implications, I consider scientific writing in its broadest context, and discuss works about science written by non-scientists, particularly fiction, poetry, and drama; the present chapter focusses on scientists as writers in order to give emphasis to the rhetorical view of their discourse.

laboratory. The examples I have selected highlight the confluence (or simultaneous operation) of expository, argumentatative, and speculative features of their discourse, especially in the case of scientific fiction. (My consideration below of the sociobiology debate also dovetails to suggest the speculative, subjective element of technical-scientific writing--i.e., the notion, raised earlier, that "facts" are intellectual constructs hardly separable from the world-view of the fact-maker.)

As discussed earlier, in technical exposition and argumentation there is a sense of building a case from the observed data, and the technical report itself constitutes a "story," the likeliness of which must be judged by fellow scientists. Popular exposition is an extension of technical exposition, but with the greater freedom of expression permitted by an "off the record" context. Thus, for instance, popular periodicals like Scientific American and The Sciences do not just translate technical information for the lay public, but take the opportunity as well to "sell" science, with a Baconian faith and enthusiasm, as a great human enterprise. In the foreword of entomologist Vincent Dethier's To Know a Fly (1962), for instance, ethologist Niko Tinbergen praises Dethier's warm, personal style and writes that society "should be convinced of the need for scientists; it should be willing and indeed eager to support them. Scientists therefore

should give their very best when `popularizing' their work" (vi). Thus, Dethier's book is not merely about flies; it is an also argument (by example) for the value to society of scientific research.[80]

The informal context of Dethier's To Know a Fly also brings out the rhetorical nature of scientific fact--fact as made, in Langer's and Knorr-Cetina's senses. For, as Dethier notes, in the end scientists present only their own view, issuing from their personal, subjective, dramatic involvement with what happens in the laboratory. Dethier's view of what a fly is all about is of his own making. Scientific exposition, with its demand for a high degree of objectivity, is nonetheless inescapably subjective and rhetorical. "By the rules of the game," Dethier writes in his concluding chapter of To Know a Fly,

> Science is supposed to be objective. This is, of course, ridiculous. As long as Science is conducted by scientists it will be subjective. There is a basic law of physics which states that in one way or another the observer always affects what he observes. This effect may be

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[80] Other examples of works like Dethier's are physicist George Gamow's One, Two, Three . . . Infinity (1947), ethologist Konrad Z. Lorenz's King Solomon's Ring (1952), microbiologist Paul De Kruif's The Microbe Hunters, geneticist George Beadle's The Language of Life (1966), biologist Lewis Thomas's The Lives of a Cell (1974), physicist Jeremy Bernstein's Experiencing Science (1978, and the many popular works by biochemist Isaac Asimov.

> infinitesimally minute or beyond all hope of measurement or it may be apparent to any dullard. But clearly between the fly and the scientist there is an interaction. What the scientist does to the fly determines in part what the fly does, and what the fly does is seen by the eyes of the scientist and sends nerve messages along his optic nerves to his brain and is there switched around and juggled and changed and eventually comes out as a thoroughly subjective observation. So, perhaps to know the fly one must also know the scientist. He is the second dramatis persona, presented after the curtain falls as is the author in all proper (and improper) plays. (111)[81]

Here, the intellectual connection of scientific discourse with the literary-rhetorical tradition is explicitly

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[81] See also in this connection Richard Schlegel's "The Impossible Spectator in Physics," in The Centennial Review, 19, 217-231, 1975. Like Dethier, Schlegel invokes Werner Heisenberg's Uncertainty Principle, as well as the often quoted statement made by Niels Bohr (in his Atomic Theory and the Description of Nature, Cambridge UP, 1934, 119) that "we are both onlookers and actors in the great drama of existence." While Dethier's study of the biology of the fly constitutes his extended example of this phenomenon, Schlegel use a specific physical problem--determining the velocity of a piece of matter that is freely floating in empty space--to show that there is "a genuine ontological dependence which does indeed force the scientist-observer in some measure to be responsible for the particular individual micro-events that he describes" (218).

acknowledged. Scientific exposition and description, notwithstanding its concern with precise empirical measurement, remains a rhetorical construct--the individual and subjective interpretation of its author.

Beyond the rhetorical aspect of popular exposition, scientists argue directly and openly in their popular writing about the scientific and technological issues facing our society. A source of confusion and frustration for the lay public with respect to such argumentation is that it is practically impossible to distinguish established scientific fact from the author's personal speculation--hard evidence from rhetorical suasion based on personal values and beliefs. Is the author explaining something that is empirically real, telling a "true" scientific story (in Medawar's sense)? Or is the author going beyond what can be concluded from the experimental data, speculating about its implications? A major example of this frustrating dilemma in our time, one which I would like to consider at some length here, is the "nature versus nurture" debate, the academic focal point of which (since the 1970s) has been the sociobiology theory of zoologist Edward O. Wilson.[82] In order to bring out the

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[82] In once again illustrating the rhetorical nature of scientific writing--this time in the popular context--I select sociobiology in particular because of recent efforts (Lanham, 1983; Winterowd, 1986) to incorporate sociobiology theory into composition theory and teaching (e.g., the notion that rhetorical style varies as a function of sociogenetic vectors for play and game). Does

rhetorical nature of this debate, it will be necessary first to explain, as briefly as possible, the claims of sociobiology theory along with its detractors' counter-arguments.

The central premise of sociobiology is that social behavior in animals, including human beings, has a genetic basis. By comprehending and accepting our own species' genetic heritage, Wilson asserts, we will be empowered to help shape human social evolution. Wilson builds his case for sociobiology in three works written for progressively wider audiences: The Insect Societies (1971), Sociobiology: The New Synthesis (1975), and On Human Nature (1978).[83] In the latter volume, he aims to persuade the public "that the time has at last arrived to close the famous gap between the two cultures, and that general sociobiology, which is simply the extension of population biology and evolutionary theory to social organization, is the appropriate instrument for the effort" (x). Not unlike B. F. Skinner's mechanistic

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the application of sociobiology to composition and rhetoric hold promise of a "new synthesis" in English studies? Or, is it a form of "scientism," warranting the same harsh attitude taken by Bizzel (1979) and Connors (1983) toward the application of Kuhnian paradigmatic theory and empiricist methodology to composition studies?

[83] See Arthur L. Caplan's The Sociobiology Debate (1978), an anthology of the reactions to the concluding chapter--titled "Man: From Sociobiology to Sociology"--of Wilson's second and most ambitious work of the trilogy, Sociobiology.

psychology, set forth for the public in his controversial Beyond Freedom and Dignity (1971), Wilson's plea in On Human Nature is for the acceptance of our sociogenetic fate: "No species, ours included, possesses a purpose beyond the imperatives created by its genetic history" (2).[84] Thus, specific behavioral patterns of cultural significance--from pair-bonding and altruism to xenophobia and aggression--are presumably programmed into the central nervous system, causing a predisposition toward those behaviors.[85]

Are we really the slaves of selfish genes? Is biology destiny? Is the human nervous system really genetically programmed for all social behavior? Are we, as a species and as individuals of that species, merely "bodies" or biological machines that evolved as a sophisticated survival strategy for our "selfish genes" (Dawkins, 1976)? Wilson's detractors, among them

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[84] See also Lionel Tiger and Robin Fox's (1971) notion of a "human biogram," a genetic "wiring" for behavior, for culture, for art, and for whatever else we may do and learn as a species; and Richard Dawkins' (1976) assertion that we are slaves to our genome, bodies (without minds?) that have evolved as a sophisticated survival strategy for our "selfish genes."

[85] Rhetorical art, too, is reduced by sociobiology to a genetotropically shaped tradition. Richard Lanham defines rhetoric as "a genuinely evolutionary theory of style--in the last analysis, a theory of behavior" (Literacy and the Survival of Humanism, 1983, 7-8, emphasis original). Thus, a stylistic option becomes a biobehavioral imperative, an instinctual drive like any other drive inherited from our ancestors.

biologists Stephen Jay Gould and Richard C. Lewontin, charge Wilson and the field of sociobiology with a groundless biologization of human nature.[86] They assert, instead, the primacy of culture over genes in shaping human social behavior. For what Gould sees as a pernicious biological determinism, he would substitute the notion of biological potentiality. "Why imagine that specific genes for aggression, dominance, or spite have any importance," Gould asks,

> when we know that the brain's enormous flexibility permits us to be aggressive or peaceful, dominant or submissive, spiteful or generous? Violence, sexism, and general nastiness are biological since they represent one subset of a possible range of behaviors. But peacefulness, equality, and kindness are just as biological--and we may see their influence increase if we can create social structures that permit them to flourish. Thus my criticism of Wilson does not invoke a nonbiological `environmentalism'; it merely pits the concept of biological potentiality--a brain capable of the full range of human behaviors and rigidly predisposed toward none--against the idea of

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[86] See Gould, "The Nonscience of Human Nature," in Ever Since Darwin (1977), 237-242.

> biological determinism--specific genes for specific behaviors. (257-258)[87]

In his review of Lumsden and Wilson's Genes, Mind, and Culture (in which the authors offer critics of sociobiology a mathematical model for the sociogenetic "multiplier effect"), Richard C. Lewontin (1981) essentially calls sociobiology a scientific fiction. He points out that all the scientific rhetoric of sociobiologists has yet to produce any evidence for a specific gene-behavior pairing. Where are the putative nucleotide sequences that code for aggression, territoriality, altruism, and so forth? In the absence of any hard evidence, Lewontin argues, biological determinism in humans must be rejected in deference to culture as a non-genetic (learned) shaper of human affairs. With the development of culture (in the anthropological sense),

> human behavior acquires a contingency and a contextual sensitivity not known among fruit flies. The social modulates and negates the individual; the incest taboo, that favorite example of sociobiologists, is a case in point. Sociobiologists confuse the universality of a social rule (incest taboo) with the occurance of an act (incest). While incest taboos may indeed

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[87] "Biological Potentiality vs. biological Determinism," in Ever Since Darwin (1977), 251-259.

> be universal, incest as an act is really quite common. The universality of an explicit rule against incest is prima facie evidence against there being a biological revulsion; if such a revulsion were built into our genes, we would need no such law. Indeed, one is hard put to think of any significant human behavior that is a stereotyped sequence like the courting behavior of Drosophila. While we cannot rule out the possibility of some genetically programmed stereotyped behavior in humans, a successful case has yet to be made. (24)

The most significant aspect, however, of Lewontin's attack against Genes, Mind, and Culture, and against Wilson personally, is his accusation of rhetorical underhandedness. Lewontin offers many examples in support of his claim that Lumsden and Wilson's book is "filled with intricate devices, rhetorical flourishes, and exaggerated claims, all meant to distract the eye. Only the most conscientious reader or reviewer can get through it without being taken in at least once." As an example of an intricate device, Lewontin explains in detail how the authors "first misstate, then misrepresent, and then misuse" Sewell Wright's adaptive surface theory with the help of "gussied-up" equations and "mathematical puffery." With respect to rhetorical flourish,

> catchy phrases and newly coined words for old concepts, `culturgen', `gene-culture adaptive landscape', `the biogeography of the mind', `ethnographic curves', and `assimilation functions' all have the air of something new and exciting but lack content, precision, or novelty. The second author is a past master of the art of rhetorical inflation, and that would seem to be his major contribution to the present book. (26)

Lewontin warns the reader against being taken in by Lumsden's model-building process, which is "not motivated either by intrinsic plausibility or by a body of fact about genes, behavior, and culture, but, like The Mikado's Pooh-ba, by a desire to `give artistic verisimilitude to an otherwise bald and unconvincing narrative'" (25).[88]

Not surprisingly, Wilson charges the Sociobiology Study Group of Science for the People (whose membership includes Lewontin and Gould) with basing their "environmentalist" theories on their own political biases and conception of "human nature." The most significant

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[88] See Gould's collections of essays, Ever Since Darwin (1977), The Panda's Thumb (1980), and Hen's Teeth and Horse's Toes (1983), which illustrate the rhetorical argumentation within the scientific community on several other sociobiologic issues, such as racism in IQ measurement. Also helpful is Arthur L. Caplan's The Sociobiology Debate (1978). In the area of genetic engineering, see Lewis Thomas's argument against "Cloning a Human Being," in The Medusa and the Snail (New York: Viking Press, 1979).

and intellectually frank comment made in the crossfire of the debaters' essays is, I believe, Gould's admission that neither "biological determinism" nor "biological potentiality" has been proven to be empirically true: "I cannot prove my scenario," Gould writes, "any more than my colleague can demonstrate his. But in the current context of no evidence, thay are at least equally plausible" (1977, 256). No scientific basis for either camp's view? No evidence? What could remain, then, but the techniques of classical rhetorical suasion, including the use of ethical and emotional appeals (Aristotle's "artificial proofs").

The point illustrated by the popular works on sociobiology is that experimental data, the numbers--whether Watson and Crick's or Skinner's or Wilson's or Gould's--may be true in themselves, physically real and empirically verifiable, but that is not enough. It is the intellectual lens through which the data are both collected and judged that is the significant dimension of scientific activity and, later, of "writing up" the experimental story. Can the observation, for instance, that caged male rats under stress (electric shock) exhibit more fighting behavior than female rats under the same conditions serve as a basis for concluding that the males are more "aggressive" than the females? "While this may be considered proof that males are <u>naturally</u> agressive,"

notes neurophysiologist Ruth Bleier (1976), "what about the equally `obvious' conclusion that females must be more intelligent, since fighting each other is clearly an ineffectual response to being shocked by some human being?" (1976, 44).

Beyond the methodological problem of measuring aggressivity by only one of its many variables is the problem of making too much of the data. "It has been a small step from such research on fighting behavior," Bleier writes, "to the speculations and observations of a host of ethologists, primatologists, sociologists and assorted defenders of the status quo that patriarchy and male domiance are inevitable, since men are more agressive than females because of inborn hormonal differences" (49). Bleier points out that, when attempting to use biological data to justify or explain sociological facts, laboratory researchers must maintain high ethical standards in presenting their findings--that their writings must be completely truthful. (There is a striking parallel here to Quintilian's requirement that a rhetor have, above all else, good character.) Scientists must acknowledge, writes Bleier, that

> with a careful selection of experimental data, it is possible to support any theoretical position. The reader has no way, short of her own literature search or research experience, to

> know that contradictory data have been omitted from the discussion. Similarly, it is possible to overinterpret the significance or the implications of data. While, specifically such techniques serve to obscure findings that challenge cherished beliefs, the general danger is that our approach to real understanding is hindered. As painful as it may sometimes seem, we had best state the facts as they seem to be and let the chips fall where they may. (57)[89]

Even if one is inclined (as I am) to agree with Bleier on the problems of collecting and discussing data without personal value-biases--as illustrated by sociobiology research--the process of communicating the facts "as they seem to be" is still a personal, value-laden rhetorical process. Complete "objectivity" is impossible. Even while to most readers their writings (technical or popular) on the biology of human social behavior will seem expository, they are actually argumentative. From the standpoint of empirical proof, neither Gould nor Wilson can as yet claim to know the complete "truth." Rather,

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[89] Other scientists beside Bleier who find the arguments for a deterministic view of human gender differences lacking in rhetorical honesty are Gould ("Women's Brains," in The Panda's Thumb), Lambert (1978), and Lowe (1978). For an interesting example in fiction of deterministic attitudes regarding sex differences, see Audrey C. Peterson, "Brain Fever in Nineteenth-Century Literature: Fact and Fiction," Victorian Studies, 19: 445-464, 1976.

they each opt for one possible version of reality.[90] Ultimately, each reader must make a personal decision as to whose version (or, in Medawar's terms, "story") to believe.

From the rhetoric of laboratory reports and of their extension, popular scientific writing, I would like to turn finally to a third dimension of scientists' rhetoric --"imaginative" or literary writing. The fact that a scientist may be able and willing to write about scientific experiences and ideas in "poetic prose" or in verse or fiction would appear to be (if C. P. Snow is right) contradictory. The rhetoric of literary art--its moral imperatives, its metaphoric vision and beauty, its stylistic and emotional freedom--is supposed to be the polar opposite of science and its controlled, measured, ethically and emotionally neutral discourse. Yet, in the context of intellectual and rhetorical history, examples can be found of quite reputable scientists who probably would have taken Thomas Sprat's proscriptions with a grain of salt. In his two-volume History of Modern Culture (1932, 1934), Preserved Smith notes that such eminent

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[90] Kenneth Burke establishes the connection between scientific discourse and rhetoric when he writes: "Even if any given terminology is a reflection of reality, by its very nature as a terminology it must be a selection of reality; and to this extent it must function also as a deflection of reality" ("Terminalistic Screens," Language as Symbolic Action: Essays on Life, Literature, and Method (Berkeley: University of California Press, 1968, 45).

scientific figures as Copernicus, Galileo, and Buffon presented their ideas with with a suasiveness highly dependent upon literary artistry. While Copernicus could "write as dryly and objectively as Euclid, he could also drive home his ideas with poetical imagery worthy of an artist," writes Smith, noting that one particular passage in Copernicus's De Revolutionibus (Book I, chapter X, on cosmic order) has been compared with the twenty-second canto of Dante's Paradiso. When used (in Smith's words) for "driving home ideas"--scientific ideas included--literary artistry becomes a rhetorical act.

It is necessary to ask here whether the apparent fusion of scientific and literary rhetorics by some scientists in earlier centuries has become, in the wake of the modern scientific revolution, a historical curiosity, a practice which has no place in contemporary scientific life and manners. In his The Seventeenth Century Background (1962), Basil Willey expressed his regret that the modern idolatry of empiricism has become a barrier to the educational cultivation of the ability to pass freely from one order of "truth" to another, a barrier to holistic knowing and self-expression. "The Cartesian spirit," wrote Willey,

> made for the sharper separation of the spheres of prose and poetry, and thereby hastened that `dissociation of sensibility' which Mr Eliot has

> remarked as having set in after the time of the Metaphysical poets. The cleavage then began to appear, which has become so troublesomely familiar to us since, between `values' and `facts'; between what you felt as a human being or as a poet, and what you thought as a man of sense, judgment and enlightenment. Instead of being able, like Donne or Browne, to think and feel simultaneously either in verse or in prose, you were now expected to think prosaically and to feel poetically. Prose was for conveying what was felt to be true, and was addressed to the judgment; poetry was for conveying pleasure, and was addressed to the fancy. (87-88, emphasis original)

This is essentially the polarized intellectual climate objectified metaphorically by C. P. Snow. Is the schism between the ancient value-oriented tradition and modern experimental factualism a real intellectual division, as Snow believed, or an attitudinal and political artifact? The late physical anthropologist Loren Eiseley asserted the latter, arguing that true scientific understanding (vs. merely fact-collecting) cannot be achieved without the help of a literary sensibility. Like Jacob Bronowski and Peter Medawar, he believed that scientific and literary creativity have a common origin. However, while

Bronowski and Medawar focussed on delineating the differences between the scientific and the artistic conceptions of reality, Eiseley emphasized the natural co-operation or complementarity of the two intellectual spheres. Beyond recognizing the differences between quantitative and qualitative understanding, he pointed out the necessity of their operational union in the search for "truth." In this sense, the notion of the two cultures was for Eiseley illusory, and he insisted that meeting points of science and art are there whether or not one chooses to grant them explicit recognition. Because of his belief not only in their common intellectual origin but in their "points of contact even in division," Eiseley asserted that "the `two cultures' are an illusion, that they are a product of unreasoning fear, professionalism, and misunderstanding" (275-276):

> Is there something here we fear to face, except when clothed in safely sterilized professional speech? Have we grown reluctant in this age of power to admit mystery and beauty into our thoughts, or to learn where power ceases? . . . If, after the ages of building and destroying, if after the measuring of light-years and the powers probed at the atom's heart, if after the last iron is rust-eaten and the last glass lies shattered in the streets, a man, some

> savage, some remnant of what once we were, pauses on his way to the tribal drinking place and feels rising from within his soul the inexplicable mist of terror and beauty that is evoked from old ruins--even the ruins of the greatest city in the world--then, I say, all will still be well with man. (278)

The significant departure of Eiseley from the two-culture conception held by Snow, Bronowski, and Medawar is his insistence that the scientific and literary imaginations, their differences notwithstanding, actually work together in each of us and that it is time to face this reality. Continuing with his forward-looking image of a savage pausing at the ruins of a past civilization, Eiseley writes:

> And if that savage can pluck a stone from the gravel because it shone like a crystal when water rushed over it, and hold it against the sunset, he will be as we were in the beginning, whole--as we were when we were children, before we began to split the knowledge from the dream. All talk of the two cultures is an illusion; it is the pebble which tells man's story. Upon it is written man's two faces, the artistic and the practical. They are expressed upon one stone over which a hand once closed, no less firm because the mind

behind it was submerged in light and shadow and deep wonder. (279)

It is difficult to tell as yet whether or not Eiseley's position represents an emergent new attitude in the general scientific community toward the relationship between the rhetoric of literary art and that of scientific inquiry.[91] The use of "poetic prose" by scientists in their writing about scientific ideas and concepts is rare. And how many scientists would expend the effort to capture the mystery and wonder of life as does Eiseley in "The Spider"?:

His science has progressed past stone,
His strange and dark geometries,
Impossible to flesh and bone,
Revive upon the passing breeze
The house the blundering foot destroys.
Indifferent to what is lost
He trusts the wind and then employs

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[91] For a helpful discussion of Eiseley's efforts to achieve a union in his writings of the scientific and poetic sensibilities, see Schwartz (1977). While G. S. Rousseau (1972) is skeptical about there being--as in the Renaissance --"men of both cultures," Eiseley insists that human beings have a natural intellectual tendency to dwell in both cultures, and that the barriers to doing so are self-imposed and perpetuated institutionally. See also Elizabeth Sewell's essay "Science and Literature" (1967), in which she develops the view that in poetry there is hope (and evidence--e.g., Walt Whitman) for the unification of poetic and scientific sensibilities; she does not, however, include examples of poetry by scientists in her discussion.

The jeweled stability of frost.
Foundations buried underfoot
Are forfeit to the mole and worm
But spiders know it and will put
Their trust in airy dreams more firm
Than any rock and raise from dew
Frail stairs the careless wind blow through.
(The Star Thrower, 155)

Eiseley's insistence on bringing together the scientific and poetic outlooks for a holistic understanding of the natural world would probably be viewed derogatively by the vast majority of his scientific colleagues as placing trust, like the spider he describes, "in airy dreams." However, whatever the long-term significance may be in the evolution of the relations between the two rhetorical traditions, Eiseley certainly is not alone in his writing about science in poetic language. Other examples are the physicist J. Robert Oppenheimer, immunologist Miroslav Holub, medicial scientists Carolin Breese Hall and Anselm Paralatore, and astrophysicist Alan Lightman (Gordon, 1985). What these scientist-poets share and convey in their poetry is the belief that reality cannot be fully explored and described in empirical language alone. The closing lines of Holub's "Evening In A Lab," for instance, express the limitations of knowledge derived solely from within the laboratory world: "Among cells and

needles,/butts and dogs,/among stars,/there, where you wake,/there, where you go to sleep,/where it never was, never is, never mind--/search/and find." The little poetry published by contemporary working scientists represents a barely audible but important voice which cries out that, as individual human beings, each of us feels the need not only for a rationalistic explanation of reality, but also for an ethical-aesthetic orientation toward that perceived reality. The combination of scientific rhetoric and literary rhetoric, these scientist-poets seem to say, is a much more powerful instrument for human understanding than either rhetoric used alone.

Just as some scientists have articulated the concerns and experience of their world in poetic prose or in verse, a few others have turned to fiction--short stories, novellas, and novels--as an outlet for scientific rhetoric. It is true that science and scientists were an important subject in fiction long before they began to occupy the pages of the sci-fi "pulps" in the 1930s, and have continued to be a theme in imaginative literature--even outside the sci-fi movement itself--to the present.[92]

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[92] Molecular biologist John Roe O'Neill in Frank Herbert's The White Plague (1982), for instance, is in some ways a modern Victor Frankenstein. I prefer using the phrase "scientific fiction" as opposed to "science fiction" simply because the latter term, associated with the 1920s movement, has proven difficult to define. Frederik Pohl (1981) defines "science fiction" as the

However, what seems rather novel--more so as a rhetorical than as a literary event--is the fact that in the past 50 years a few scientists have extended the rhetorical range of scientific discourse by combining it with the rhetoric of fiction, of imagined worlds peopled with imagined scientists and laboratories and discoveries. Though C. P. Snow's talents as both a scientist and a novelist may have been, as Robert Gorham (1965) characterizes them, mediocre, this should not obscure his accomplishments intellectually and rhetorically as a living bridge between two world-views, and as a pioneer in the present-day scientific community (i.e., among doctorally-trained researchers) in the writing of scientific fiction. Other scientists after Snow (himself a physicist) who have written scientific fiction are biochemist Isaac Asimov, biomedical scientist Michael Crichton, experimental psychologist B. F. Skinner, biophysicist Thomas McMahon,

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literature of change, and cautions that

> the word `science' should not be understood too literally in the term. . . . There are many works, undeniably entitled to wear the label `science fiction', which have nothing to do with science. Such writers as Ray Bradbury, Harlan Ellison, J. G. Ballard, and Kurt Vonnegut are certainly writing science fiction (though some of them would deny it), but they are also certainly not writing about science; for them science is irrelevant and even technology is only a metaphor. (6)

My point here is that the literature with which I am presently concerned is literally concerned with science and scientists, and with their place in human affairs, so that I use the term "scientific fiction" to make this distinction.

and physicists Russell McCormmach, Carl Sagan, David Brin, and Gregory Benford.

The scientific fiction written by these and a few other scientists is significant from the standpoint of rhetorical history, for, here is the kind of discourse--imaginary, metaphoric, emotional, personal, subjective--that Thomas Sprat urged the scientific-minded to repudiate. Here, in the manner and purpose of the language used--for pleasure versus for truth-seeking--is the supposed dividing line between the literary and scientific traditions.[93] And when scientists write about science in the manner of the literary artist, in novels, where is that supposedly distinct line between scientific rhetoric and the rhetoric of fiction, or between Snow's two cultures? This is of course exactly what Eiseley makes the readers of his poetic prose contemplate. In the context of fiction, David Brin (1987) notes that the boundaries between science and science fiction sometimes are not too clear, citing as an example the subject of many of his own stories--exobiology or SETI (the search for extraterrestrial intelligence). The chief point I wish to reiterate, and to illustrate briefly here, is that the use by scientists of the techniques of fiction in writing about their experience and ideas extends the range

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[93] See I. A. Richards' Poetries and Sciences (1970), where he distinguishes between poetic truth and scientific truth in terms of emotive versus logical statements.

and power of scientific rhetoric. Scientific fiction permits the scientist-writer to examine the personal-ethical dimension of science, and to construct and argue for models of scientific activity which suggest the larger social and moral implications of what happens in the laboratory. Such models are, in terms of both the scientist's and the reader's personal value-system, self-confrontational. They provoke reflection on the question, "What do I believe?"

For instance, Snow's novel The Search could almost be called a case study in scientific ethics. The young chemistry researcher Arthur Miles is discovered by a colleague to have made a major error in a technical report already published; this simple technical mistake costs Miles his induction into the Royal Society. While his was an honest mistake, due to momentary carelessless regarding a simple technicality, a few months later Miles catches his close friend and colleague Sheriff in the act of falsifying experimental results: "He had committed the major scientific crime . . . Sheriff had given some false facts, suppressed some true ones" (345). Miles' failure of nerve to send his drafted letter to the journal exposing Sheriff's dishonesty means his irrevocable break from science: "The passion was over now." Beside the rhetorical purpose of convincing the reader that there indeed are moral values--to be adhered to religiously--

bound up with scientific activity, Snow's 1958 edition of The Search had a further rhetorical aim--one connected to his two-culture argument: Non-scientists could learn from the novel something about what it is like to be a scientist.[94]

In the past 30 years other scientific novels published by scientists have offered, like Snow's The Search, a picture of the modus operandi of science and its practitioners, including attention to relevant ethical, social, philosophic, and/or historical contexts. Michael Crichton's Terminal Man (1972) is a neuropsychiatric patient who willingly submits to an experimental biofeedback wiring protocol, only to find (with the reader) that he is being treated more like a rat than a

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[94] In the foreword of his 1958 revision of The Search, Snow raises the two-culture argument that was the subject of his Rede Lecture a year later, including the stereotypes held by each culture of the other: "The scientists' stereotype of the literary culture: defeatist, unvirile, profoundly selfish, unconcerned about their brother men, indifferent to the social condition, intellectually untruthful. The literary stereotype of the scientist: brash, shallowly optimistic, indifferent to the individual condition, lacking all sense of tragedy, unemotional, naive, asexual" (vi). Consistent with Snow's belief in education as the chief way to correct these stereotypes, another rhetorical aim of his novel is, then, the presentation of what he perceives to be an accurate picture of scientific life, manners, and learning. It is lamentable that Snow, having had the distinction of being a member of both cultures, seemed to be concerned exclusively with scientific education, and appears to utterly neglect (except ironically by his personal example) education in the literary arts, as if the latter will somehow take care of itself; not to mention the importance of exploring the complementarity of the two cultures in the learning process.

human being; even when it becomes apparent to the neurobiologists treating him that the treatment (intended to control neurologically his aggressivity) has failed, the scientists continue their experiment in the interest of further data, over the objections of the female member of the team who has fallen in love with the doomed patient. Crichton asks his reader to ponder: Is this the kind of medical science our society should tolerate?

Two novels by physicists which deal with the ethical side of science and scientists in earlier epochs of revolutionary scientific activity are Thomas McMahon's Principles of American Nuclear Chemistry (1970), on the Los Alamos atomic bomb project in the 1940s, and Russell McCormmach's Night Thoughts of a Classical Physicist (1982), on the transition in the late nineteenth century from the Newtonian to the Einsteinian picture of reality. Neither of these novels brings the reader into the laboratory scene itself, as does Snow's story, but both deal even more intensely than Snow with the personal lives of the scientists performing the research and show how their lives and personal values are completely intermeshed with their scientific work. The personal lives of the physicists in McMahon's Principles--as recalled years later in the quiet, intimate conversation of one of the principal researchers and his physicist son--are as depressing and self-destructive as the monstrosity

that they created in the Nevada laboratory. Asked by his son whether the Los Alamos research changed him, the father can only point somberly to the abhorrent militarization of nuclear research: "He smiled, but it was a vacant smile. When I looked at him, he seemed to be gazing into a desert: his own image of the emptiness of physics as a modern thing to do. Its unconcern. Its narrow professionalism. Its spiritual poverty" (239-240). In Night Thoughts, McCormmach conveys the same image of physics research as McMahon's, though in a far different time and setting--1870s Germany. In 1918, 69-year-old retired physicist Victor Jakob reflects on his 50-year career, focussing on such matters as objectivism versus subjectivism in the construction of scientific truths, and the chaotic indeterminacy and uncertainty of reality in the age of quantum mechanics compared to that of classical Newtonian mechanics, which seemed to him more comprehensible and unified. Like McMahon, McCormmach uses the techniques of fiction to explore and comment on a historical event; the main characters involved in both novels are not fully developed people, as in biographical or realistic fiction, but used only as representative figures, as a way of organizing their view of the events that form the subject of their work.[95]

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[95] In the Afterword of Night Thoughts, McCormmach writes: "I have constructed a composite physicist from real voices and events of the past. Jakob is invented,

The novels by McMahon and McCormmach are rhetorical in that they construct a personal view of the scientific enterprise in the context of historical change and the associated ethical contingencies. Two examples of novels by scientists which are outright arguments for a change in the future course of action in the application of scientific knowledge to societal issues are experimental psychologist B. F. Skinner's controversial Walden Two (1976) and astrophysicist Carl Sagan's Contact (1985). Skinner's novel pictures an experimental commune which is founded on behavioristic education; though his mechanistic approach to learning has met fierce opposition in favor of more humanistic educational strategies, his novel remains as another example of a scientist using literary art to treat (in this case, to argue for) scientific ideas. In Contact, Sagan uses fiction to promote the search for extraterrestrial intelligent life; in his story, contact

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but his outlook and activities belong to many of the real physicists who were his contemporaries. Every detail in the invented physicist's career is based upon the careers of real physicists, and every detail I attribute to real physicists comes from the historical record" (159). McCormmach also appends a bibligraphical essay to detail this point. To support his picture of the prevalent anti-semitism among European scientists during this period, for instance, he cites Leopold Infeld's discussion on the matter in Quest: The Evolution of a Scientist (New York: Doubleday, Doran, 1941). He also cites a host of scientific autobiographies, biographies, histories, technical journal articles, letters, and obituaries which he used in constructing Jakob's life in physics, his views on local and world affairs, and his reflections on changing technical aspects of physics.

is actually made with an alien intelligence by an international team of astrophysicists, only for the team to be doubted and ridiculed by humanity since the means of contact is almost practically impossible for anyone else beside the participating scientists to comprehend--a realistic scenario which is not uncommon with respect to the process of societal acceptance of revolutionary scientific discovery. Sagan's novel is a rhetorical effort, similar to Skinner's, to convince his reader to place faith in the problem-solving power of science--in his case applied not to educational issues but to cosmic ones.[96]

A final rhetorical use of fiction by scientists which must be mentioned is the futuristic-speculative writing of Isaac Asimov, Gregory Benford, and David Brin. Isaac Asimov is without question the most prolific writer of scientific and technological fiction within the small group of scientists who write fiction. He has written

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[96] This great religious faith in astrophysical science which Sagan exhibits in Contact, and toward which he hopes to attract converts (from the ranks of the skeptics), is also evident in his self-produced television series Cosmos, about which Thomas M. Lessl (1985) notes:

> As an attempt to portray science as a righteous force, as a holy movement culminating in the cosmic drama, Sagan projects a moralistic vision of science, a theodicy vindicating the ethical integrity of the scientific way. As such, as communication not just about what is and is not but also about what is good and bad, Cosmos has its rhetorical roots in the traditions of religious discourse as much as in the scientific. (185)

many dozens of short stories and novels since the 1940s in which he presents extrapolative scenarios of interplanetary travel, space colonization, and biosocial evolution, including (in his latest fiction) speculations about computer-mind interfacing; his most ambitious and far-reaching work is the continuing Foundation series, set more than 20,000 years into the future.[97] Asimov, and more recently Sagan, have been inspirational to Brin and Benford, whose stories are set anywhere from decades to millions of years into the future and constitute meditations on time, memory, and the human species' place in the universe.[98] Like Asimov, Brin and Benford speculate extrapolatively about future technological advances derived from basic astrophysical research activity, particularly interplanetary travel and habitation; and like, Snow, Skinner, Crichton, and Sagan exhibit a unshakable faith in the problem-solving power of scientific methodology in present and future worlds, even while some of the problems they address may in part issue from scientific activity itself (e.g., genetic

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[97] He began this series with The Foundation Trilogy (1951)--Foundation, Foundation and Empire, and Second Foundation--and resumed it in the early 1980s with three more novels, containing speculations in such areas as computers and mental telepathy.

[98] Both Brin and Benford have published several novels and numerous short stories. See for instance Brin's recent collection of stories (all published during the 1980s) titled The River of Time (1987), and Benford's Artifact (1985) and In the Ocean of Night (1987).

engineering, overpopulation, artificial intelligence, and nuclear power). A great part of the rhetorical aim of their fiction is, in fact, to propose possible solutions to the problems which they perceive to already exist or which they anticipate in the biosocial evolution of our species.

As I hope to have shown in this chapter, to think of scientific writing in narrowly technical terms is erroneous, for the rhetoric of scientists extends well beyond the standardized models of laboratory discourse. Moreover, the popular and literary (especially fictional) rhetoric of scientists comprise an important outlet for their exploration of, and argumentation about, the ethical implications of what they do professionally. Clearly, as David Brin points out in many of the postscriptural comments to his stories, the professional journals in astrophysics would never consider accepting for publication the kinds of meditations he develops in his fiction, though they arise legitimately from research observations. In the following chapter, I consider the pedagogical usefulness and implications of a rhetorical view of scientific writing in a liberal education. In that context, I discuss scientific writing in its broadest definition, focussing on composition pedagogy as well as on the complementary uses in the English classroom of scientific literature by non-scientists.

CHAPTER III

THE PEDAGOGY OF SCIENTIFIC WRITING

In the first two chapters, I sought to bring out the rhetorical context of scientific writing, both in the way such writing evolved and in its range of expression. I wished to show that scientific writing developed contiguously with, rather than in isolation from, the rhetorical tradition; that the scientific plainness ethic reflects an attitudinal orientation emphasizing "thing-ness" over the words themselves. However, I also pointed out that a manner of writing that is totally plain--i.e., devoid of metaphor and figurative language, completely objective and unambiguous, and purged of emotion and the individual writer's character, is rather mythical, even in technical scientific writing.[99]

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[99] In his autobiography, microbiologist Salvador E. Luria (1984) comments as follows on scientists' contrasting styles:

> Just as an experienced listener can tell which [violin] virtuoso is playing, so an experienced scientist can often tell which virtuoso is the author of an important scientific paper. The differences are not just in the writing, but in the thinking and the quality of experimentation: from the terseness of Al Hershey's or Charles Yanofsky's work, to the almost whimsical quality in Seymour Benzer's research and writing and lecturing; from the

In technical scientific writing, I noted further, the laboratory researcher has the task not only of communicating clearly the experimental results, but of convincing a specialized readership that the particular interpretations set forth with respect to the collected data are viable. Technical writers must tell believable stories. Thus, contrary to being produced in a rhetorical vacuum, scientific writing is shaped by rhetorical imperatives of its own, serving the needs and purposes of both the individual scientist-writer and the aims of scientific activity generally. Moreover, as illustrated by the case of the sociobiology debate, the rhetorical aspects of scientific writing are magnified as the audience broadens to include non-specialists and the general public. An extension and diversification of scientific rhetoric is evident, too, in fiction (and to some degree, poetry and poetic prose) by scientists.

The diachronic and synchronic study of scientific writing reveals the natural connection between scientific and humanistic ways of knowing and their shared dependence on language, on the rhetorical manipulation of verbal signs and symbols. By "rhetorical manipulation" I mean the shaping of language to achieve a specific effect on a

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> slightly baroque manner of Sol Spiegelman to the aggressive mode of Seymour Cohen. Each of these leading biologists is distinct in style because each if a unique self and projects that self into every aspect of his work. (159-160)

particular audience, whether that effect be to enlighten, to entertain, to persuade, or some combination thereof. As Peter Dixon (1971) points out, if stress is laid on the part of the definition of rhetoric which concerns the speaker's or writer's impact on his audience, then rhetoric can be stretched to include

> almost the entire area of human discourse, since most of our speech and writing (even much of our soliloquizing) is directed to an audience, however small). The concern of rhetoric becomes nothing less than the whole complex business of communication through language, the intricate network of relationships which connects a speaker (or writer) with those he addresses. (2)

Within this broad sense of rhetoric, scientists no less than humanists may be viewed as rhetors. The connection between rhetoric and scientific fiction is also evident since, as Dixon notes, "as a literary-critical term, rhetoric in this broader sense will cover all the techniques by which a writer establishes rapport with his readers, and by which he elicits and guides their responses to his work" (3).[100]

In the present chapter, the point I want to make is

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[100] Here Dixon cites Wayne C. Booth's use of rhetoric in his Preface to The Rhetoric of Fiction as "a detailed study of `the author's means of controlling his readers'" (3).

that an understanding of the place of scientific writing within the rhetorical tradition will make a lasting imprint in our culture only when attention is given to the practical applications of that understanding in the sphere of education. Indeed, the study of scientific writing would be incomplete without its consideration as a recognized area of academic study--as a classroom activity. More specifically, I will develop and illustrate the assertion that engaging students in reading and writing about science creates opportunities for raising and illuminating a series of fundamental questions, including: What is the intellectual relationship between scientific and humanistic modes of learning? Do they inform one another? Notwithstanding the presuppositions and stereotypes that abound, what exactly is "science"? What is "art"? How is a poem or fictional narrative different from a scientific theory in intent, in cognitive and affective processes, and in uses of language which led to its creation and by which it achieves its effect? Is a poem or novel less truthful, less real, less "useful" than a textbook on molecular genetics? Do imagination, human values, and "personality" have any relevance to scientific writing?

Before proceeding, I must note here that what I mean by "scientific writing" in this chapter is much broader than the usual concern with technical or journal article

writing by scientists. A narrow definition of scientific writing as technical journal writing is exemplified by Charles Bazerman's recent study of the rhetorical nature of such writing in his Shaping Written Knowledge: The Genre and Activity of the Experimental Article in Science (1988). Bazerman does recognize that beside the journal article, "many other genres of great significance have energed in the sciences. Important stories remain to be told about theoretical articles, reviews of literature, speculative articles, handbooks and other reference works, proposals, and various pedagogic genres--their separate histories and interrelationships" (7). However, my own concern is even broader than the body of technical scientific writing produced by scientists. Within the term scientific writing, I include non-technical writing about science--works written by scientists as well as by writers outside the scientific community: popular scientific works and literary writings (fiction, poetry, and drama) dealing centrally with scientific ideas, themes, and characters.

Only when students are engaged in reading and writing about science in this larger context of the widest possible range and diversity of language uses will their intellectual perspective be broadened to the point of comprehending the interdependence of all modes of knowing in piecing together one's personal view of reality. In

this challenging task, scientific and artistic domains of thought and activity are not mutually exclusive in intellectual and practical terms, but co-operate in ways that elude simple explanation. Moreover, the elusiveness of a straightforward definition of the relationship between the two intellectual traditions or processes is in part due to the ongoing evolution of that relationship; the latter is, in other words, not simply an objective "given" entity but something that we as individuals and as a culture create.

When approached rhetorically--as a process involving an interplay between competing views and uses of language --scientific writing (in its broadest sense) can be used to draw students into the center of the ongoing dialectic between the "ancient" and "modern" world-views. Reading and writing about science holds the potential not only of helping students to work out for themselves the validity of scientific-humanistic <u>distinctions</u> which constitute our culture's "climate of opinion," but also of focussing their attention on the possible <u>complementarities</u> of these two intellectual traditions as they forge a comprehensive explanation of our world, of what we as human beings are and of what we can or should be. An understanding of scientific writing as a range of rhetorical options-- rather than as being monolithically and technically plain --encourages the development of a holistic outlook on

learning, thinking, writing, reading and their dependence on how human beings manipulate language with different aims and audiences in mind.[101] Since, as James Britton (1975) has emphasized, it is through the manipulation of language that human beings are able to shape a world-representation for themselves, it would follow that students should experience a multiplicity of language uses, spanning the humanistic and the scientific realms of thought and activity.

Given its established foci on literature, composition, and language, the field of English studies is in a position to exercise leadership in the use of reading and writing activities which immerse students in the kind of dialectic I have mentioned. As a core component in the

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[101] In his delineation of the features of scientific discourse, Kinneavy (1971, 88-89) is correct in stating that such discourse is referential and "thing"-oriented. However, his overall discussion is misleading in at least two important respects. First, he states that because of the referential character of scientific discourse, "the reader as a target of persuasion, emotional or otherwise, intrudes only indirectly and implicitly." As I attempted to show in the preceding chapter, scientists employ various means of persuasion, even in their technical writing. Second, Kinneavy's exclusive concern with technical scientific discourse, and his omission of scientists' writing for wider audiences, leads him to assert that scientific discourse is non-literary: "A discourse which becomes noticeably expressive or directly persuasive or literarily preoccupied is a discourse which is in danger of becoming nonscientific." While it is true that popular (including literary) scientific writing is not a major form of scientists' discourse, these forms are heavily referential as well as persuasive and emotive. In relation to Kinneavy's scheme, the referential-emotive distinction attempted long ago by I. A. Richards (1925) also is difficult to uphold categorically.

liberal arts curriculum, English studies can serve in part as an important (and perhaps the only) integrative force in the academic community, demonstrating in particular how writing about science is no less rhetorical than other kinds of writing. The English classroom can foster, more easily and with more energy and time than the "content" areas, the broadest possible range of reading and writing experiences, including not only a structured sampling of the diverse writings by scientists but also, side by side, writings about science by humanists and imaginative literature dealing with scientific themes and ideas.

As I noted in my Introduction, A. N. Whitehead pointed out in his Aims of Education that the three chief components of a liberal education--the scientific, the practical, and the literary--must somehow be more integrated than they are in order to achieve a true balance of intellect and character through liberal education. A liberal and liberating education is one that does not distort the importance or contribution of one area of knowledge or intellectual "culture" in relation to the others, but nourishes instead the ability to use any and all modes of thinking and manipulating language in the process of educational and personal development. Again, while such a multidisciplinary or holistic intellectual perspective can and should be nurtured in every content area (up and down the educational system), I am arguing

that the English classroom--as the college curriculum's enclave of literary, composition, and language study--has a special opportunity and responsibility to do so.[102]

In his discussion of "interdisciplinary English," James P. Beck (1980) argues that students must be taught to make use of as many disciplines as possible, not as "bins of fact," but as perspectives, as intellectual lenses. Beck grants that there are differences and conflicts across the disciplines, that "each lens differs in terms of basic questions asked, basic presuppositions, scope of subject-matter, operating methods and research, even the use of language." (30) Nonetheless, reading and writing activities which are integrative--i.e., structured to emphasize the cooperation of all the lenses in fully explaining reality--create opportunities for students to develop an "explict awareness of the many paths to the elephant of reality" (32). Interdisciplinary English is a way to teach, too, that no one of these paths is inherently more intellectually promising or superior to

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[102] My focus here on the pedagogical uses of scientific writing in the college curriculum should not obscure the importance of, and successful experimentation with, the incorporation of scientific thinking and writing in the secondary and elementary curricula. See for instance the suggestions for the secondary school teacher by Neil Ellman and Lynda Chittenden's work with elementary schoolchildren in Barr et al.'s What's Going on?: Language/Learning Episodes in British and American Classrooms, Grades 4-13 (1982). A more recent resource for the secondary teacher (but also adaptable for college teaching) is Dale Worsely and Bernadette Mayer's The Art of Science Writing (1989).

the others, and that all the paths are paved with the medium of language. There is a certain cross-disciplinary unifying power in the notion that all areas of learning depend on language and that, language being as imperfect as it is, words resist being held to absolute, unequivocal meanings, even in science. This shared linguistic indeterminacy itself puts all the disciplines on an equal intellectual footing.[103]

Before turning to a discussion of specific uses of scientific writing and scientific literature in the English classroom, I would like to point out certain professional biases, tacitly held by many educators within and without the field of English, which work against the establishment of a place within English studies of scientific writing and reading. A fundamental bias, one which I have challenged in the first two chapters, is that rhetoric and scientific discourse have little or nothing

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[103] In terms of the kind of integrative, dialectical approach which I am proposing, there is a significant difference between the concepts of interdisciplinary English and writing-across-the-curriculum (e.g., Fulwiler and Young, 1982; Fulwiler, 1984). The latter appears to focus on improving writing skills--clarity, readability, and so on--relevant to a given content area. Interdisciplinary English holds the potential, on the other hand, for encouraging the integration and interfacing of a spectrum of rhetorical forms, from the informational/expository to the imaginative/literary, for promoting the kind of holistic thinking to which Beck refers. In this regard, then, interdisciplinary English can both include and move beyond the concerns of cross-curricular writing programs by engaging students in a greater diversity of reading and writing experiences than those limited by specific content-area preoccupations.

to do with one another. It is true, as James Raymond (1982) and Robert Connors (1983) assert, that rhetoric and science are different methodologies or systems of inquiry developed for different purposes. Raymond notes that while science is concerned with empirical certainty, rhetoric

> deals with questions that science methodically excludes: questions about values, ethics, esthetics, meaning, politics, justice, causality involving human motives, and causality involving an indeterminate number of variables. In short, physics can tell us how to build a nuclear reactor, but it cannot tell us whether we ought to build one, or whether, on balance, the costs will outweigh the benefits. (781)

The crucial distinction between rhetoric and science, in Raymond's view, is expressed in a quote from Aristotle's Nichomachean Ethics (I.3): "It is the mark of an educated man to look for precision in each class of things just so far as the nature of the subject admits; it is evidently foolish to accept probable reasoning from a mathematician and to demand from a rhetorician scientific proofs" (782). Connors, concerned specifically with the relationship between composition studies and science, adds:

> The push for science in our field at the present time can lead all too easily to scientism,

> placing methodology at the heart of rhetorical education and tilting composition studies toward the sort of mechanistic concerns with neutral `techniques' that we wish in our best moments to transcend. As Richard Weaver constantly reminds us, we as rhetoricians must be concerned with a wider realm than are scientists--for scientists are concerned only with facts and the relationships between them, while rhetorical concerns must include both the scientific occurrence and the axiological ordering of these facts. (19)

Both Raymond and Connors warn against allowing the intrusion into English studies of pseudo-scientific methodologies which distort the aims and purposes of a rhetorical education.[104]

The view that rhetorical and scientific methodologies differ in fundamental ways does not mean, however, that scientific writing is a-rhetorical, i.e., that it has nothing to do with the Classical modes of suasion and argumentation, or with human feelings and value-judgments. As Elizabeth Harris (1982) notes, it is this narrow view of scientific writing as a "practical," mechanical skill

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[104] Neither author argues, however, against the appropriate use of empirical methods--as opposed to "imitation science"--in composition research. (Presumably, they mean the kind of research cited, for instance, by Stephen North, 1987, 141-196.)

which, has led some teachers and scholars to question the so-called "liberal-arts approach" to technical writing, or "any approach to research or scholarship in scientific and technological texts which employs concepts and methods primarily from the liberal arts: literary theory and history, traditional and modern rhetoric, linguistics, and the philosophy and history of science and technology" (628). Harris points out two disturbing pedagogical implications of this "anti-academic" perspective on technical writing: first, that "we already know or will casually find out everything we need to know about technical writing in order to teach it, and second, that "the use of language to construct whole discourses in real situations can be taught by simple prescription and imitation" (629). These assumptions, in Harris's view, fail to recognize "the complexity of the language object, it relation to the situation in which it is constructed, and the subjective experience of constructing it. . . . [They suggest] insensitivity to the variables and subtleties of all natural-language texts" (629).

Beside having to answer to biased assumptions regarding the dividing points between the humanistic-rhetorical tradition and scientific discourse, the liberal arts approach to studying scientific writing meets resistance from the "heritage model" of English studies (Bosmajian, 1980; LaConte, 1980). The heritage model has

dominated English studies since its establishment as a discipline in the late nineteenth century, and as a pedagogical tradition it has roots in earlier centuries (Applebee, 1974, 10-11, 34-36). Under this model, the chief concern of English studies is the teaching of the great works of poetry, drama, and fiction written by the celebrated British and American authors through the centuries. While valuable, this model of the profession tends unfortunately to neglect the pedagogical importance of non-fiction (Rygiel, 1984) and contemporary literature, although since the 1960s the teaching of the latter has increased considerably (Donelson, 1977). In addition, the heritage model works against the classroom uses of science-related literature, no doubt largely because of the historical tension between Snow's two cultures.

Yet, despite these rhetorical and literary biases against scientific reading and writing, in recent years scientific fiction and non-fiction have been included in anthologies for introductory composition and for students in the sciences.[105] Two examples of such texts are Mary Elizabeth Bowen and Joseph A. Mazzeo's Writing About Science (1979) and Robert E. Lynch and Thomas B. Swanzey's The Example of Science (1981). The common humanistic-

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[105] Teachers of English in the schools, too, have an extensive science literature avaliable for their classrooms; see, e.g., Judy (Tchudi), 1980; Chittenden, 1982; and Armstrong, 1982.

rhetorical approach of these works is evident; the authors view science and scientific writing as a human, creative activity stamped by the individual scientist's personality and style. Beyond the stimulating content of their selections, the authors aim to demonstrate the rhetorical range and sophistication of the scientist-writers, including the extent to which the writings are self-referential: "By the very act of telling us about the world, these authors say more than perhaps even they are aware they are saying about themselves" (Bowen and Mazzeo, xxiii).[106]

The humanistic-rhetorical approach to teaching scientific writing, which is the focus of the remainder of this chapter, contrasts sharply with another major pedagogical approach in the field--that of prescriptivism.

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[106] There is one significant difference in the pedagogical approach of these two texts. Bowen and Mazzeo focus on rhetorical modes--e.g., definition, description, classification and enumeration, comparison/contrast, argument/persuasion, and analogy. Lynch and Swanzey, on the other hand, in seeking to show in part "that the stages of the act of science are fundamentally the same as the stages of other creative pursuits" (x), organize the first five of their eight chapters according to the scientific method--"Defining the Problem," "Observing the Evidence," "Forming the Hypothesis," "Experimenting," and "Presenting the Theory." The major drawback of Lynch and Swanzey's format is that it gives the impression that scientific inquiry is straightforward, a notion questioned by P. B. Medawar and others. In his Preface to The Double Helix, for instance, James Watson notes that "science seldom proceeds in the straightforward logical manner imagined by outsiders. Instead, its steps forward (and sometimes backward) are often very human events in which personalities and cultural traditions play major roles."

Examples of texts in the prescriptive tradition--which emphasizes the traditionally acceptable or "correct" forms of laboratory note-taking and technical report writing--are Donald H. Menzel et al.'s Writing a Technical Paper (1961), Robert Barrass's Scientists Must Write (1978), and Melba Jerry Murray and Hugh Hay-Roe's Engineered Writing (1986).[107] The differences in pedagogical philosophy and practice between the prescriptive and humanistic-rhetorical approaches to teaching scientific writing are exemplified respectively by Morris Freedman's "The Seven Sins of Technical Writing" (1958) and E. Fred Carlisle's "Teaching Scientific Writing Humanistically: From Theory to Action" (1978). While Freedman's approach is characterized by advice on how to avoid certain stylistic and grammatical "sins," Carlisle focusses on the human, value-laden, more subjective elements of language in scientific writing, and includes a consideration of the wide range and diversity of writing by scientists and about science, recognizing that scientists write more than just laboratory notes and reports.[108]

The point which I would like to develop and

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[107] For an example of the prescriptive approach in a writing-across-the-curriculum text, see Maimon et al. (1981), 257-326.

[108] For other examples of the prescriptive approach in teaching technical scientific writing, see Barloon (1954), Zisowitz (1964), Booth (1975), and Binkley (1977).

illustrate, then, is that scientific reading and writing in the English classroom can be used to engage students in activities other than (and beyond) those intended to develop "practical skills." Again, what I am suggesting is a pedagogical approach which permits a consideration of the intellectual meeting points between the humanistic and scientific traditions. As Joan Digby and Bob Brier (1985) note in the preface to their collection of readings in science and literature, the world-view that we each develop through a liberal education is the result of a cross-fertilization of the humanistic and literary traditions with the scientific one; thus, students should be encouraged "to reflect on the two [traditions] together and how the interaction of their language and ideas causes permutations of human thought." The major aim of engaging students in scientific reading and writing, therefore, should be to bring together the diverse uses of language by scientists and humanists (particularly literary artists) which exhibit both the common and divergent views of reality of their respective intellectual traditions. I hope to demonstrate that the pedagogical approach that is best suited for accomplishing this aim is that of thematic reading/writing units.

The notion of thematic units in English studies has an extensive history. As Arthur Applebee (1974) notes, such units became established in anthologies for secondary

English teaching by the 1930s.[109] Currently, the thematic organization of anthologies for college English is widespread, as illustrated by such collections as Sheena Gillespie and Linda Stanley's Someone Like Me: Images for Writing (1984), Douglas Hunt's The Dolphin Reader (1986), and Mary Lou Conlin's Patterns: A Short Prose Reader (1988). Themes in these works range from simple categorizations like "People," "Emotions" and "Choices," to groupings within "The Natural Environment," "The Man-Made Environment," and "Animals and Man." (Several scientists' writings are represented in these anthologies, including Loren Eiseley, Konrad Lorenz, Richard Selzer, and Lewis Thomas.)

The use of thematic teaching units permits a broadening of pedgagogical concerns in English studies beyond those of genres, periods, and particular authors and works. The thematic approach reflects a concern with the personal growth of the learner versus an emphasis on

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[109] By this time, thematic units centered around important personal or social goals were often combined with the "experience" approach. See for instance the final report of the NCTE-appointed Curriculum Commission, An Experience Curriculum in English (1935), which recommended such "experience strands" as "Exploring the Physical World," "Studying Human Nature," "Giving Fancy Rein," and "Sharing Lyric Emotion" (Applebee, 119-120). Such studies of secondary English anthologies as Arno Jewett's 1959 English Language Arts in American High Schools and James Lynch and Bertrand Evans' 1963 High School English Textbooks show that the thematic approach became even more firmly rooted though the 1950s and into the 1960s (Applebee, 169-171).

specific literary works as objects worthy of study for their own sake. In the context of the historical tension between the two cultures, thematized reading and writing experiences can be used to focus students' attention of constructing their own view of the intellectual relationships betweeen the humanities and the sciences--particularly the fact that both modes are inquiry are dependent on language and human values.

In the area of science writing/reading, Anne Eisenberg (1986) suggests three kinds of thematic units that can be used with students in engineering and technology. Her first suggestion is a unit on "The context of Discovery," which would have students read (and presumably write on) accounts of moments of great scientific discovery, such as those of Charles Darwin, Marie Curie, Friedrich Kekule, Albert Einstein, and James Watson. Eisenberg's also suggests units on "Science as Debate" (treating such issues as spontaneous generation and astro-archeology) and on the patent, which might include such documents as those on suspenders by Mark Twain and on dresser trunks by Lillian Russell. However, the kinds of thematic units which I will suggest and illustrate in greater detail in the following pages are more in line with the earlier considerations I raised with respect to creating chances for immersing students in the two-culture dialectic. They would have students

confront their own and our culture's attitudes and biases regarding scientific-humanistic distinctions. These biases are at the heart of the ongoing dialectic between competing world-views, and they are the basis upon which delineations are drawn between ways of learning. Here the ground is soft. Words like "rhetoric" and "literature" are as difficult to define as "science" and "experiment" and "the scientific method." Ultimately, defining such terms (and others like them, such as "religion," "politics," and "mind") is an arbitrary, rhetorical act. Individually, we can define them as broadly or as narrowly as we wish. The definitions we construct for ourselves ultimately become, to borrow the words of Mark Johnson (1980), "metaphors we live by."

When the definition of scientific writing is broadened beyond a narrow association with technical reportage of laboratory experimentation, to include popular and imaginative writings about science by both scientists and non-scientists (particularly literary artists, in light of the two intellectual poles defined by Snow), students can be given opportunities to see the basic <u>connections</u> across the disciplines in the context of rhetorical and linguistic choices and processes. As examples, I will detail three reading/writing units which would have students focus on the ethical aspects of "revolutionary" science, on the place of "normal" or

routine science in everyday human affairs, and on defining "the scientific process" itself. I would like to emphasize here that my illustrations of thematic units are presented not as tested-and-proven ideas, but rather in the spirit of William Strong's "An I-Search on Language/Composition Research" (1986)--except that the works on my list are those which have been helpful in my personal attempts to make sense of the relationship in our culture between the humanities and the sciences. Also, in contrast to Strong's chronological groupings (from the mid-1960s to the mid-1980s), I find it more convenient to categorize my selections on the basis of the kinds of questions, issues, or themes that they invite the reader to explore. However, regardless of how the works are divided, the point I wish to make is that their collective effect should allow the reader to take part meaningfully in the ongoing dialectic between the humanistic and scientific world-views, in something like Bronowski's searching "The Abacus and the Rose: A New Dialogue on Two World Systems" (1965).

I begin, then, with a unit of fiction which raises the issue of what biologist Leonard Isaacs (1986) termed "the Frankenstein scenario"--the conducting of revolutionary scientific research driven by an obsessive, often self-serving personality whose priorities are

confused.[110] Heading the works that can be included in this group is of course Mary Shelley's classic Frankenstein, which for Isaacs "embodies and dramatizes many of the most frightening dilemmas that have resulted from the advance of twentieth century science," especially in the areas of nuclear physics (since Oppenheimer and Los Alamos) and genetic engineering. The hubris of Victor Frankenstein, who finally discovers the cause of animation only to unleash upon humanity a "filthy creation," is present in other fictional scientists. The protagonists of Nathaniel Hawthorne's "Rappaccini's Daughter" and "The Birthmark" are brilliant life scientists who, ironically, lack a sense of the timeless verities of the heart and soul. Rappaccini's actions, for instance, have wider significance than the nineteenth century debate over the respective virtues and drawbacks of allopathic versus homeopathic approaches to medical treatment (Uroff, 1972); and, far less than an attack on science itself, the tale is a warning against the abusive excesses of unregulated experimental science.

Likewise, the scientists in some of the stories in the sci-fi "pulps" of the 1920s and 1930s (Ashley, 1974, 1975) are obsessed with achieving great breakthroughs and

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[110] As a scientist, Isaacs showed a genuine concern with the uses of fiction for immersing students in science and society issues; see his short but useful study Darwin to Double Helix: The Biological Theme in Science Fiction (1977).

give little or no forethought to their possible darker side when actually applied. Two good examples of this are the physicist Avery in Charles Willard Diffin's "The Power and the Glory" (1930)--whose creation of a mechanism that generates great power based on "the disintegration of the atom" is today easily recognizable--and the biochemist Beetle in John Taine's "The Ultimate Catalyst" (1939), who creates a fungus to do away with hardened criminals. (Taine is the pen name of the CalTech mathematician Eric Temple Bell.) There are a number of other literary works which serve as examples of Isaacs' Frankenstein scenario, including H. G. Wells' The Island of Doctor Moreau, Karel Capek's play R.U.R. (Rossum's Universal Robots), Aldous Huxley's Brave New World (worth reading with Huxley's Brave New World Revisited and biologist Lewis Thomas' essay "On Cloning"), George Orwell's 1984, Fred Mustard Stewart's The Methuselah Enzyme, William Kotzwinkle's Doctor Rat, Michael Crichton's Terminal Man, Robin Cook's Coma, and Frank Herbert's The White Plague.[111]

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[111] A useful framework within which to engage students in discussion of these novels, and of many of the works I mention below in the other thematic units, would be the five "Mertonian norms" for the behavior of academic scientists (Ziman, 1984, 81-90). These norms--dealing with such concepts as the communalism of scientific knowledge and the personal disinterestedness of the researcher in relation to his work--essentially define a scientific ethos, an ideal pattern of behavior to be followed by all scientists. Sociologist R. K. Merton first proposed the norms in 1942; the original papers in which he set them forth are reprinted in his The Sociology of Science (Chicago: University of Chicago Press, 1973).

The works in the first group deal with the scientist's moral responsibility to society. In depicting science at its worst, they constitute a rather cathartic experience--a denouncement of a flawed scientific ethos, one founded principally on self-glorification, and at the same time a re-affirmation of positive human values. (An analogy could be made here with Quintilian's requirement that a rhetor be of good character above all else.) This next group contains works which are connected thematically by their bearing on the matter of the place in our society of routine or "normal" science (in Thomas Kuhn's sense), as opposed to those less common moments of scientific activity which are marked by revolutionary breakthroughs and their applications. The authors of these works suggest answers, frequently controversial, to the question: What is the place of science in everyday human affairs?

A good initial literary spark for taking up this question is Francis Bacon's 1624 utopian dream-vision New Atlantis (profitably read with P. B. Medawar's equally optimistic essay "On `The Effecting of all Things Possible'"). Though unfinished, the historical significance of New Atlantis lies in its alluringly detailed and prophetic sketch of Solomon's House, a great scientific research foundation which thrived independently of the political, economic, and religious systems of its

host society, and which became a reality in 1662 as The Royal Society of London.[112] Beside Bacon's tale (a remarkable instance of the complementarity of the literary and scientific imaginations and of two rhetorical orientations), several other works of fiction offer their own commentary on the place of science in society. Charles Dickens' Hard Times and behaviorist B. F. Skinner's Walden Two, for instance, express different (and in some ways opposing) views of the place of science in learning. Who can forget the "eminently practical" Grandgrind ranting in M'Choakumchild's classroom about the importance in life of "Facts"? Substitute "facts" for "things" and one can almost hear in Gradgrind's preaching the equally fervent voice of Thomas Sprat. "Now, what I want is, Facts," exhorts Gradgrind, "Teach these boys and girls nothing but Facts. Facts alone are wanted in life. Plant nothing else, and root out everything else. You can only form the minds of reasoning animals upon Facts; nothing else will ever be of any service to them." sir!"

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[112] Included in Thomas Sprat's 1667 History of the Royal Society is another work which could be included in this second unit of readings--Abraham Cowley's "Ode to the Royal Society." Cowley's poem draws attention, for instance, to the conflict which continues in our time regarding the relative importance of Words and Things in the search for "true" knowledge; speaking of Bacon, Cowley writes:

> From Words, which are but the Pictures of Thought,
> (Though we our Thoughts from them perversely drew)
> To Things, the Minds right object, he it brought,
> Like foolish Birds to painted Grapes we flew;
> He sought and gather'd for our use the True . . .

Life was not to be lived in the manner of the fanciful Sissy Jupe, girl number twenty, the circus-man's daughter, but rather like her classmate, Bitzer, who could describe and classify a horse for M'Choakumchild in concrete, exact, and "real" terms. Check the Fancy, encourage the Reason. Coketown itself is a cold, hard fact made up of many smaller cold, hard facts: "Fact, fact, fact, everywhere in the material aspect of the town; fact, fact, fact everywhere in the immaterial." While Dickens' Hard Times caricatures the excesses of utilitarianism and empiricism, Skinner's novel Walden Two is more in the vein of Bacon's utopia in that it projects a vision of the ideal method of learning, presented popularly in his controversial Beyond Freedom and Dignity (1971). Several novels by scientists which explore the place of science in society futuristically and extrapolatively have already been mentioned in the previous chapter, including those of Isaac Asimov, David Brin, and Gregory Benford.[113]

With respect to the debate concerning biological determinism, discussed in the chapter two in the context of the rhetoric of sociobiologists, a few examples of novels which will provoke a lively consideration of the

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[113] A recent novel which deals with the place of technology (applied science) in present-day American culture, depicting a technological overkill in our daily lives--e.g., from radio transmissions, sirens, and microwaves to ultrasonic appliances, television overstimulation, and industrial pollution--is Don DeLillo's White Noise (1984).

topic are Emile Zola's Rougon-Macquart series of "experimental" novels, such as Germinal and Nana, August Strindberg's By the Open Sea, and Harold Frederic's The Damnation of Theron Ware or Illumination. Zola's pervasive use of animal imagery in Nana, for instance, suggests that the characters described are trapped in their own biological heredity, that they are animals more of instinct than of reason. The audience at the Theatre des Varietes, where Nana performs, sound like twittering sparrows; the men waiting in Nana's foyer are likened to "bow-wows sitting round on their behinds; the lawyer Venot eats "with a small nibling sounds suggestive of a mouse; Countess Sabine "might have been a cat, sleeping with claws withdrawn and paws stirred by a scarce perceptible nervous quiver; the cheering crowds at the Grand Prix looked "like insects swarming madly" and their cry was "a wild beast's cry despite the garb of civilzation." Nana herself, at the center of Zola's veritable zoo of characters, becomes in the end "the fly that had flown up from the ordure of the slums, bringing with it the leaven of social rottenness"; her capricious denigration of Muffat and Parisian society "was an affair of unconscious hereditary spite; it had come to her in her blood."[114]

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[114] In his 1880 essay "The Experimental Novel," Zola envisioned a natural partnership between the laboratory scientist and the experimental novelist, whom he defined as "the one who accepts proven facts, who points out in man and in society the mechanism of the phenomena over

The question of biological determinism is also treated in the plays The Hairy Ape (1921) and The Adding Machine (1923) by Eugene O'Neill and Elmer Rice, respectively. Both of these plays deal with the dreadful possibility of an inescapable, evolutionary-determined nature of one's lot in life. Rice mocks the idea of "progress" itself: the adding machine that replaces the main character Zero only becomes in his next life a "super-hyper-adding machine," which will require even less of his intellect to operate, further demeaning him as a human being. The "gorilla-like" Yank in O'Neill's play is at much at the mercy of heredity as Rice's Zero. Other plays which deal with the place of science and scientists in society more directly are Friedrich Durrenmatt's The Physicists (1962), and Heinar Kipphardt's In the Matter of J. Robert Oppenheimer (1968).[115] While the plays by Rice and O'Neill pose the question of the biological basis of human behavior, the plays by Durrenmatt and Kipphardt

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which science is mistress, and who does not interpose his personal sentiments, except in the phenomena whose determinism is not yet settled, and who tries to test, as much as he can, this personal sentiment, this idea a priori, by observation and experiment" (Ellmann and Feidelson, 1965).

[115] See Daniel L. Zins' essay "Teaching English in a Nuclear Age" (1985), which discusses both Durrenmatt's The Physicists and Kipphardt's Oppenheimer, as well as Bertolt Brecht's play Galileo (New York: Grove Press, 1966). The conclusion to the latter play, quoted by Zins, also reflects the theme of the other two plays: "May you now guard science's light/Kindle it and use it right,/Lest it be a flame to fall/Downward to consume us all."

engage the reader in equally difficult questions about the ethical relationships between scientific research and the sociopolitical concerns.

Beside the themes of Frankensteinian science and the place of science in society, a third thematic unit can be organized around the definition of science as a mode of inquiry and as a way of viewing reality: How is "doing science" different from and similar to other, non-scientific or humanistic activities? What kinds of human values does science engender? What is the role of creativity and imagination in scientific activity? No small part of the tension between the humanities and the sciences is due to the elusiveness of achieving a clear, comprehensive, and mutual understanding of what each is--as a process of thought and action, as a methodology for learning, as a world-view, and as a human experience rooted in values and language--though definitions and differentiations have been attempted by both scientists (Einstein, 1936; Heisenberg, 1955; Medawar, 1967; Bronowski, 1978) and non-scientists with various backgrounds and interests, including literary artists and English educators (Arnold, 1889; Richards, 1925, 1926; Huxley, 1963; Levin, 1968; Bizzell, 1979; Raymond, 1982; Connors, 1983). Possibly indicative of a recent change in the posture of scientists toward the humanistic-rhetorical tradition is Bronowski's assertion in Magic,

Science, and Civilization that "the method of science, the objectification of entities, abstract concepts, or artificial concepts like atoms, in in fact a direct continuation of the human process of language, and that it is right to think of science as being simply a highly formalized language" (49).

There are number of works of fiction and non-fiction which provide stimulating entry points for shaping and testing definitions of science--works which offer examples of the scientific imagination, the value-systems of science, and the language of scientists in its social context. I have already mentioned in chapter two a few novels by scientists which depict scientific problem-solving activity or scientists grappling with important issues of their time--e.g., Snow's The Search, Sagan's Contact, and McCormmach's Night Thoughts. In addition, there are a number of works by literary artists which can help the reader comprehend scientific activity and the life and manners of scientists. Examples of these are Sinclair Lewis's Arrowsmith (which could be read with Paul De Kruif's The Microbe Hunters), Ursula K. LeGuin's The Dispossessed, Irving Stone's biographical novel on Charles Darwin, The Origin (which might be read with Darwin's Autobiography), and three of John Steinbeck's works--his short story "The Snake," his novel Cannery Row, and The Log from The Sea of Cortez, a literary account of a

Darwinesque collecting expedition with his close friend Edward Ricketts, a marine biologist who is also the main character in the other two stories. To these works might be added Hawthorne's sketch "Earth's Holocaust," the thematic preoccupation of which is with the distinction between the external, material manifestation of human values--influenced by the progress of science--and their inner, spiritual origin.

In addition to these works of fiction there is a substantial body of poetry by scientists and literary artists which deals with the activity and values of science. "Scientific poetry," or poetry which employs scientific concepts, themes, and images, has a history going back at least to the seventeenth century (depending on one's definition of "science"). There is a mixture of purposes expressed in such poetry, ranging from the merely descriptive to the critical and laudatory. A few examples by literary artists since the nineteenth century are Edgar Allen Poe's "Sonnet--To Science," William Wordsworth's "The Tables Turned," Walt Whitman's "When I Heard the Learn'd Astronomer," Robert Frost's "Why Wait for Science," and John Updike's "Cosmic Gall." Poems about science and scientific values by scientists include James Clerk Maxwell's "Molecular Evolution," Miroslav Holub's "Evening in a Lab," and Eva Royston's "Working in

the Laboratory."[116] Two contemporary examples show the differing attitudes held toward experimental science. In "Working in the Laboratory" (Poems of Science, 312) Royston expresses the comforting routine and exactness of laboratory work, versus the limitations of science expressed by many of the above-cited poems:

> Working in the laboratory
> You're exact, if nothing else.
> I like my whitecoated sterility.
> I count fear in terms of adrenalin.
> The rabbit's pickled fur intoxicates me.
> I slice the strings of intestine. Yes, of course
> I can hear the afternoon sun knocking
> Against the window like a timid visitor,
> When I go home, I'll whip eggs,
> And read. But now my rubber hands
> Dip into ethyl alcohol
> Jars, like drifting embryos, demand a label.
> There's so much tissue.
> Of course I can look up suddenly
> And smile like a child.
> In the meantime, I weigh this cellular butter

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[116] Many other examples of "scientific poetry" can be found in such collections as Ralph B. Crum's Scientific Thought in Poetry (1931), John Heath-Stubbs and Phillips Salman's Poems of Science (1984), and Bonnie Bilyeu Gordon's Songs From Unsung Worlds: Science in Poetry (1985).

Against the stone,

And like my whitecoated sterility.

By contrast, Anne S. Perlman's "The Specialist" (Unsung Worlds, 168) beseeches the researcher to step outside the abstract confines of the laboratory to view nature more directly:

He no longer marvels at stars.
That's what.

Under the telescope's dome,
he crouches in a
concrete basement,
his head down,
decoding the graphs
a cosmic camera
drops in his lap.

In his own regional head
(it could be a dungeon)
he parses electrical impulses,
regroups the lines
(fudging a little)
into lakes and sandstorms,
peaks and tide wracks,
his whole territory
shut against tresspassers

Poems about science by both scientists and poets provide another way, in addition to fiction and drama, to explore not only the contribution of scientific methodology and thought to everyday human affairs but also the place of a literary sensibility in the scientific life and manners.[117]

The fiction, drama, and poetry I have mentioned can of course be complemented by narrative accounts of scientific activity by scientists themselves, such as those found in autobiographies.[118] I have already mentioned Vincent Dethier's To Know a Fly, Konrad Lorenz's King Solomon's Ring, and James Watson's The Double Helix. The latter work, an account of the race to discover the molecular structure of deoxyribonucleic acid (DNA) is particularly revealing with respect to the social process of scientific activity and the role of ethics in science, and should be read with the alternative and conflicting account by Anne Sayre, Rosalind Franklin and DNA, and the essay "A Sorrow and a Pity: Rosalind Franklin and The Double Helix" by physicist Jeremy Bernstein. Must reading

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[117] Such considerations are taken up in the introductory dialogue between Alan Lightman (an astrophysicist) and George Starbuck (a poet) in Gordon's Unsung Worlds (1985).

[118] Recent autobiographies are microbiologist S. E. Luria's A Slot Machine, A Broken Test Tube (1984), from which I quoted earlier, chemist Primo Levi's The Periodic Table (1984), and physicist Richard P. Feynman's "Surely You're Joking, Mr. Feynman!" (1985).

with all of these works is P. B. Medawar's little book Advice to a Young Scientist, which includes a chapter on sexism amd racism in science.

The three thematic units I have outlined--on the Frankenstein scenario, science and society, and defining science--bring together voices from the literary and scientific communities to foster a constructive clashing of two major intellectual traditions, the kind of educational experience which, as Snow argued, is urgently need in our highly specialized schooling, and which would help overcome the fragmented condition of liberal education described by Whitehead. It is difficult to say whether there could emerge from this clashing an Hegelian synthesis in the form of a new consciousness and rhetoric, perhaps something neither fully scientific nor fully humanistic but a complementary fusion which (like the two strands making up a DNA double helix) becomes a third force with greater potential for expression and growth than either intellectual lens alone.[119] Even if such a synthesis or co-operative merging of the two world-pictures were possible, how could one know for certain if it happened? What means of assessment of changed attitudes, new perspectives, and/or personal growth could be used as a reliable and valid yardstick? Despite such

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[119] I am not in agreement with Rousseau (1972), who apparently believes that the two cultures cannot co-exist within one individual.

nagging questions, the potential value in the English classroom of the thematic units I have discussed is enormous. At the least, the sensitive reader will be drawn into the center of the two-culture dialectic, the lasting benefit of which is likely to be a heightened critical attitude with regard to making judgments about the relationship between the humanistic and the scientific disciplines--an attitude which must begin with the premise that neither mode of inquiry or picture of reality is inherently superior to the other. Moreover, if the teaching of English is largely a political act, as suggested by some English educators (Moffett, 1981; Zins, 1985; Ohmann, 1974, 1985), thematic units provide a viable opportunity to identify and scruinize biased or stereotypical conceptualizations of both the humanist and the scientist, and to nurture a peaceful cooperation between the two cultures.

Finally, I would like to add a brief remark on classroom writing activities associated with science. Clearly, while the thematic units just presented will provide structured contexts for writing assignments, a number of other writing exercises, not necessarily linked to science reading, can be used to encourage students to bring together the perspectives of the two cultures and to explore the subtle complexities of their relationship. Students can write science dialogues (Wilkes, 1978), try

"webbing" (Abruscato and Hassard, 1976), or perhaps write and produce short television ads that rely on scientific proof of the product's value. Additional possibilities are the writing of technical reports based on actual field research (Lewis, 1978), science fiction, plays dealing with science in relation to human values, and sensory poetry.[120] Lastly, even in technical report writing, students can be encouraged to use rhetorical devices as a way to personalize their presentation of scientific information. In their experiments of this sort with technical writing students, Whitburn et al. (1978) observe that the use of such rhetorical devices as climax, parenthesis, polysyndeton, antithesis, and alliteration

> promote such traditional ideals in technical writing as economy and clarity. They encourage a student to be a more aggressive writer and let his personality through on nonspecialist communication. They strengthen the belief that writing is an art that can be learned and not a talent inherent in the genes. They help with invention, the discovery of content. They arouse

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[120] Examples of sensory poetry on scientific themes written by high school students are given by Worsley and Mayer (1989), 60-63. Such poetry may help students visualize metaphorically their observations of natural phenomena.

reader interest. (357)[121]

I reiterate the point, in closing, that the kinds of science writing that are encouraged by the thematic units I have set forth, and by the suggestions made in the preceding paragraph, are clearly not founded on a "skills" model of composition. An emphasis on the mechanistic aspects of writing short-changes the deeper dimension of using language which goes beyond the words themselves. "What we are looking for in English," David Holbrook wrote in English for Meaning, "is not merely a technical skill . . . but a particular orientation towards the world through words, which devotes itself to the discovery of truth and meaning of experience" (229). The English classroom, where more attention is given than anywhere else in the curriculum to language, is the ideal place to create holistic learning structures, to encourage the development of multi-disciplinary and bi-cultural (in Snow's terms) perspectives. Reading and writing constitute not so much a source of facts or a set of

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[121] See also Whitburn's "Personality in Scientific and Technical Writing" (1976) and Jerome Bump's "Metaphor, Creativity, and Technical Writing" (1985). Bump believes that metaphor "is one of the scientist's as well as one of the poet's most powerful tools" and that (in agreement with Max Black) "metaphorical models are in fact indispensible tools for the generation of creative hypotheses and effective explanations in science" (447). Therefore, he suggests, journal writing and directed exercises are two ways to encourage students of technical writin to engage in metaphorical thinking. (Bump does not provide specific examples of writing assignments.)

skills, but deeply personal experiences through which readers and writers build their self-concept, shape and test their view of the world, and celebrate the multifariousness of language, ideas, and human experience. It is time, as Robert Shafer (1986) suggests, to implement more widely models of English education based on the points of agreement in the personal growth movement.

CONCLUSION

The words "scientific writing" suggest to some a mode of using language that is diametrically opposed to the "colors" of traditional rhetorical forms of discourse and, indeed, that the writing of experimental scientists is not rhetorical at all. Thomas Sprat's rejection of rhetoric on behalf of his fellow Baconians constituted an attempt to purge the language of the new science of the subjective, ambiguous, and emotional qualities which permeated the discourse of those who had hitherto measured learned discourse by a Ciceronian eloquence--by the skillful use of the figures of speech and thought revered since antiquity. When Peter Ramus reduced rhetoric essentially to considerations of style, a practice which gained wide acceptance among seventeenth century educators at all levels of schooling, the stage was set for a clash between the ancient and modern uses of language. "Plain language," in the context of the emergent linguistic needs and aims of modern science, meant arhetorical language. Classical models of learned discourse did not, the new scientists argued, focus on objective, material reality--on <u>things</u>--but on words as an end in itself. Scholastic

disputation in particular represented for the new scientists an abuse of words, since the physical world, the Book of Nature, was not the central source of reference.

In the first chapter, I wished to show that the scientists' new conception of plainness, notwithstanding its rootedness in physical nature, was shaped by rhetorical constraints of its own. The four great arts of traditional rhetoric--invention, arrangement, style, and memory--have had no less a place in scientific activity and writing than in humanistic modes of inquiry and discourse. This point is developed further in chapter two by a demonstration of the subjective, argumentative elements present in the wide range of writing by scientists. Whether one considers the technical scientific article, the popular writings by scientists, or their fiction, rhetorical argumentation--persuasive discourse--is a fundamental dimension of the writings of scientists. With respect to the technical and popular writings by scientists, the sociobiology debate spurred by the writings of E. O. Wilson is representative of such persuasive discourse, though any number of other examples might be chosen which are far less visible and dramatic.[122] The argumentative nature of scientists'

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[122] See for instance the detailed case study by Charles Bazerman (1988, 193-225) of the technical publications of the physicist Arthur Holly Compton, in

writing becomes increasingly evident as the audience of scientist-writers widens to include those readers outside a particular community of specialists; only the language in which the arguments are framed changes, not the essential purpose of persuading a readership to accept the view being presented of the natural phenomena being considered, whether the latter be organismic (including human) behavior or the behavior of atomic particles subjected to experimental manipulation.

Finally, in the third chapter, I argue that at the broadest audience level of scientific writing, most notably that at which it intersects with literary art, the rhetoric of science can be seen as emanating from and belonging to an authorial and linguistic community larger than that of laboratory researchers. Scientific writing ultimately becomes, then, a co-participatory process which comprises a dialectic between the humanistic and empirical traditions. The central point of chapter three is that

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which Bazerman shows the rhetorical framework of Compton's attempt to persuade his colleagues of the validity of what eventually came to be known as the Compton Effect, a phenomenon claimed to occur when electrons are scattered by x-radiation. Bazerman writes that Compton

> creates a crispness of argument not only by detailed revisions of the representation of the experiment and the results, but also by his careful control of the epistemic level, authorial voice, and authorial judgments. His persuavive ends can only be met if he maintains the confidence of his readership that his representation on all levels adheres to the current standards of scientific practice. (224)

scientific writing must be taught in the liberal arts curriculum as comprising such a dialectic. The limits of scientific knowledge and methodologies, the promise of the scientific age, must be set in relief against cautionary scenarios like those of Aldous Huxley in Brave New World, Michael Crichton in Terminal Man, or Frank Herbert in The White Plague. The cosmic, futuristic dramas imagined by phsycists David Brin and Gregory Benford, as well as those pictured by biochemist Isaac Asimov, are necessary reminders that the same physical power that holds the potential to propel the human species through vast galactic expanses also could, by the exercise of opposing ethical values, destroy entire civilizations. All of these speculative stories, whether authored by scientists or by literary artists, are part of the rhetoric of modern science, no less so because (as Brin notes) they cannot ever make their way into the technical periodicals of the scientific community. The language of science, its argumentative rhetoric, can be fully undertood and appreciated only when it considered in its multifarious forms and seen for what it is, a dialectic between the individual rhetor's personal values and beliefs on the one hand and, on the other, the irrepressible desire to find order in, and thereby to control and shape, the material world.

The past three centuries have been characterized by

the "modern" ideal of virtually limitless progress engendered and sustained by the scientific revolution born in the seventeenth century. The modern revolution in science is, in a real sense, a rhetorical re-orientation. As individuals of the western world who have benefitted from the great technological advances made possible by experimental research we have come to revere a fact-world, in a way not too dissimilar from the way Dickens' Gradgrind worshipped facts. The rhetoric of media advertisements, for instance, constantly bombards its targetted audiences with experimentally-derived facts to back the claims made for all sorts of products. Facts are worshipped (even if they often intimidate), as are the scientists who generate them.

This factualistic orientation in modern culture is evident as well in our colleges and universities, where scientists and the scientific curriculum typically overshadow the contributions of humanists and humanistic studies. The voice of fact, of science and technology, speaks louder and more convincingly than the voice of art --and particularly, needless to say, than the voice of literary art. It is in this very context of competing intellectual perspectives--perspectives dependent for their coherence upon identifiable and agreed upon (if not explicitly stated) uses of language--that English studies can serve as an integrative discipline. The English

classroom can serve as a base for bringing under close scrutuny the languages of both scientists and literary artists in order to explore the ways in which both depend upon imagination and creativity in forging, and arguing for, particular views of reality. As Bronowski and Medawar have repeatedly stated, both scientific hypotheses and poems are imaginative constructs which must be re-created and re-interpreted in the mind of their audience.

Moreover, the combined study of scientific and literary uses of language can help students integrate what Jonathan King (1986) calls "the three faces of thinking"--the empirical, interpretive, and evaluative dimensions of human endeavor. The language of empiricism, the mark of the experimental sciences for the past three centuries, must be accompanied by the language of contexts, King asserts, a language which provides an interpretive framework in which to place empirically-derived facts. Such an interpretive framework is offered by the language of analogies, metaphors, models, paradigms, ideologies, stories, and myths. "Such prophets as Huxley and Orwell," writes King,

> told us stories of what could be but should not be, precisely in the hope that we would alter the script. Without such stories we cannot experiment with visions; we cannot compare them. With no comparisons, we run great risks in our

> collective lives, for a society with false visions is just as dangerous as a society with no visions. (85)

The third face of thinking, which King terms "evaluative," is concerned with moral development. Rationalistic, utilitarian thinking historically has tended to exclude completely questions about right and wrong, and has focussed near-sightedly on a concern with merely producing empirical knowledge. It is evaluative thinking which is the basis upon which, for instance, Oppenheimer questioned the wisdom of creating nuclear weaponry or, more recently, the biologist Lewis Thomas (1979) warned against experimentation leading the capability of cloning the human genome. It is the same kind of thinking exemplified by Michael Crichton in Terminal Man--a commentary on the self-serving laboratory ethos as much as it is a research thriller like Gregory Benford's Artifact--or by C. P. Snow in The Search or Hawthorne in "Rappaccini's Daughter" or Kate Wilhelm in The Clewiston Test.

We live in a "post-modern" world (Magill, 1977)--a world which no longer measures "progress" by the lone yardstick of scientific ratiocination and technological advancement, particularly since the latter have also brought a host of new problems (from environmental pollution to the spectre of nuclear holocaust). Beyond a concern with practical "skills" and vocation, a liberal

curriculum should be, first and foremost, integrative; it should develop an understanding of the co-operative and complementary relationship between the humanities and the sciences.[123] The study of scientific writing in the broadest sense, from its plainness ethic to its rhetorical extension into imaginative literature, offers a powerful context and means for achieving this purpose.

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[123] In his 1958 address to the American Association of University Professors--titled "Science and Humanities in Education"--chemist Eugene Rabinowitch remarked, in line with the climate of opinion anticipating Snow's Rede Lecture on the two cultures, that just as humanistic study must incorporate "the characteristics of open-mindedness and tolerance, the principles of relativity and complementarity, which modern science has evolved . . . science cannot remain an activity unrelated to the humanistic principles and values which mankind has evolved in its history. . . . [The scientist] has to learn to integrate science with the humanities, and not to place the two mechanically one beside the other" (Obler and Estrin, 1962, 170-171, my emphasis).

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