A Syllabus for English 346K,

Writing in the Natural Sciences and Technology,

focusing on supplementary texts in the sciences

by

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with the support of

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I. Origin and Rationale of the Course

On April 20, 1981 the University Council of the University of Texas at Austin approved a proposal for a new undergraduate university requirement in English. In the words of that proposal, "the heart of the change in the proposal is the transfer of the second required composition course from the second semester of the freshman year to the junior or senior year and to require that the subjects of the themes be relevant to the particular discipline of the student."

"Certainly the most compelling reason for the suggestion is the desire of the UT faculty and student body. . . . The faculty involved in such programs [at other universities] almost universally praise the greater maturity of the themes, the better organization of the material, and the more noticeable motivation of the students. . . . Our experience here at Texas with the courses in technical writing and advanced expository prose agrees with these findings."

The new upper-division writing course is to be called "E346K: Writing in Different Disciplines" and is to be offered in four versions: Writing in the Arts and Humanities, Writing in the Social and Behavioral Sciences, Writing in the Natural Sciences and Technology, and Writing in Business. According to the course description approved by the department of English in May, 1980, "readings are to include classic and contemporary expository essays and books in these disciplines, and some selections which concern the social, ethical, and philosophical aspects of the disciplines."

In the department meeting of May 1, 1981, Professor Elizabeth Harris, Chair of the Natural Sciences and Technologies subcommittee for this course, suggested that "this is an upper-division course in the kinds of writing in pure and applied sciences. The basic purpose of E346K, Writing in Natural

Sciences and Technologies, is to enable students to do the kinds of writing those fields require. In addition, the course aims to increase students' critical awareness of the intellectual models and value-dimension of those fields."

"To write effectively in the sciences and technologies, students must master general writing skills and some special ones, must learn to research the professional literature in those fields, and must become familiar with the formats in which scientific and technological writing commonly appears."

"This course is organized primarily to review and strengthen general writing skills, to introduce appropriate special skills and formats, and to give students practice in library research in their professional fields. Individual units of the course focus on developing skills such as writing with particular scientific and technological aims, writing for particular scientific and technological audiences, using specialized vocabularies, organizing various kinds of scientific and technological writing, avoiding stylistic problems characteristic of scientific and technological writing, and researching professional literature."

"The writing assignment in each unit is an exercise of the particular skills the unit focuses on, as well as an exercise of basic writing skills. During the course, students will produce about six pieces of writing in various formats, including a library research report. While instructors may sometimes assign writing topics, they will also encourage students to choose topics from their own fields -- to write as professionals in their fields."

"Readings in classical and contemporary scientific and technological literature provide, among other things, models of some particular skills and/or occasions for their use by the student. Readings to include classic and contemporary essays and books in these disciplines, and some selections which concern the social, ethical, and philosophical aspects of the disciplines.

"Our current thinking is that required texts for the course will include

Mills, Gordon H. and John A. Walter, Technical Writing, plus one book of readings, plus the further option of The Structure of Scientific Revolutions by Thomas Kuhn. Current candidates for the readings include Writing About Science (an anthology by Mary Elizabeth Bowen and Joseph A. Mazzeo), and single longer works such as James Watson's The Double Helix, the Norton Critical Edition of Darwin, Theory of Relativity by Bertrand Russell, The Tacit Dimension by Karl Polanyi, and The Ways Things Are by Percy Bridgeman. The choice of a book of readings and the option of The Structure of Scientific Revolutions will depend somewhat on the individual instructor's approach to developing students' critical awareness of value-dimensions of their fields."

According to the minutes of this meeting, "there was general discussion of the aims and objectives of the course and of the balance between reading and writing required of students. Dr. Harris said that the subcommittee envisaged the course as an upgrading of E317, 'Technical Writing.' (E346K replaces the sophomore writing courses as well as E307 and E308. Except for phase-out sections satisfying some students' catalogue requirements, the department would no longer offer E310 or E317. 'Technical Writing' could be offered at the advanced level, e. g. E333K.) The course would concentrate on teaching students to write scientifically rather than to write about science. Students would learn to write about technical subjects so that both peers and educated non-specialists would be able to understand what the writer was talking about. John Walter believed this was very important; students don't get this kind of writing instruction in their technical subjects."

"Other faculty members believed that the course should be designed from a humanist pespective. Wayne Lesser urged that the thrust of the course be to encourage students to evaluate and critically analyze works in their own fields; the English Department should provide students with broad, general education rather than with technical education. Robert Twombly wanted more emphasis on reading. . . . "

To resolve some of the differences that became increasingly apparent in the department discussion which followed I propose to take the one book required in the original course description, Mills' and Walter's Technical Writing, and relate it to a number of possible supplementary texts which fulfill the requirement that some of the selections must concern the social, ethical, and philosophical aspects of the disciplines. Our debate about E346K was in some respects a microcosm of the larger debate that has been conducted for over a century now between the sciences and the humanities. I believe not only that the two cultures can relate to each other better than they have in the past, but also that the kind of interdisciplinary thought required for their interaction should be the primary goal of a university. Otherwise, as Clark Kerr has argued, it might more accurately be described as a multiversity.

More specifically, my aim is to demonstrate that there are many texts available which can make the teaching of E346K, Natural Sciences and Technologies (hereafter abbreviated as 346K-NST), attractive to teachers whose training has been in the humanities rather than in the sciences. Not only do these texts concern social, ethical, and philosophical aspects of the natural sciences and technologies, they also demonstrate that there are many elements of the scientific method that might appeal to teachers trained in the humanities; that there are many connections between the sciences, technologies, and the humanities; and that there are many aspects of scientific rhetoric that will interest teachers of English, including the role of emotion, personal pronouns, metaphors, rhetorical awareness, and even "poetic" stylistic effects in scientific writing. Metaphors are particularly interesting in this context becuse of the work of Max Black on metaphor in the sciences and the humanities and works such as Robert Frost's "Education by Poetry," which discusses Darwin, Einstein, and Heisenberg as well as poetry.

II. Available Resources for the Teaching of Technical Writing

First of all, however, we need to emphasize the need to teach technical writing in this course, for it is designed for students in science and engineering and is intended to fulfill many of the functions formerly performed by E317, the technical writing course. Fortunately, perhaps because the best technical writing text in the country (Mills' and Walter's) is a product of this department, many resources are available to the teacher new to technical writing.

There is in fact a 276 page Course Resource Book for E317, Technical Writing, edited by Elizabeth Harris, as part of a project for the improvement of teaching in E317 funded by the Vice-President for Academic Affairs in the Spring of 1978, and revised by Professor Harris in the Spring of 1981. As she states in the preface, "included are some theoretical articles, samples of several instructors' course policies and syllabi, a selection of assignments and classroom activities that some instructors have found successful, and a selection of essays from which some instructors compile their own anthologies. . . . Much of the material here has been specifically designed or adapted for use with Gordon Mills and John Walter, Technical Writing, 4th ed. . . . As the sample syllabi show, there are several different ways of organizing E. 317, and few instructors proceed directly through the textbook. For easy reference, however, the order of assignments and course activities, after the syllabus section, follows that of Mills and Walter." Instructors are encouraged to remove pages on assignments and course activities and xerox them directly for class distribution. The theoretical articles include John Walter's introduction, "Technical Writing: Species or Genus?" Elizabeth Harris's "Applications of Kinneavy's Theory of Discourse to Technical Writing," and Carolyn Blackman's "A Bibliography of Resources for Beginning Teachers of Technical Writing."

In addition to these theoretical articles in the E317 Course Resource Book others are available in the English department such as John Walter's "Teaching Technical Writing: Resources and Strategies" and Technical Report Form by John Walter and Ronald Stroud (Austin: University Cooperative Society, 1973), a model technical report often required along with the Mills' and Walter's text. Moreover, as chair of the subcommittee on the science and technology version of E346K, Professor Elizabeth Harris prepared a six-page draft syllabus divided into six units: I. Aims, or Purposes, of Writing in the Sciences and Technologies; II. Sources of the Entities and Events that Different Sciences and Technologies Write About; III. Writing to Inform; IV. Writing to Demonstrate; V. Writing to Explore; VI. The Library Research Paper or Report. Each unit includes a statement of objectives, page assignments in Mills and Walter, suggestions for writing and class discussion, and some suggested theoretical and critical readings for teachers in authors such as Kinneavy, Barthes, Jakobson, Geertz, Hayakawa, Landes, Moffet, Morris, Rockas, Newton, and Kuhn.

Resources are also available outside the department for technical writing teachers. The library regularly prepares materials for the library research proposals and reports. For instance, they have provided E317 technical writing teachers with a valuable, five-page guide, "Teaching the Research Elements of the Library Research Proposal and Report," which is designed to be used in conjunction with chapters fifteen, twenty-two, and twenty-three of the Mills and Walter text. In addition, early in the semester they have provided E317 teachers copies of the materials involved and a memo explaining how to get classroom sets. The sets include:

(1) "Subjects for Technical Writing Research" for various disciplines: engineering, life sciences, computer sciences, nursing, and business.

(2) A self-instructional worksheet for each of the four disciplines. Besides the usual focus on finding a topic, background information, and periodical articles, the students are directed to the library that serves

their discipline, the standard sources in their discipline, and how to locate technical materials. They are also given assignment instructions on how to evaluate periodical articles and write abstracts of them.

(3) A bibliography of important sources in each discipline.

The teacher's guide also discusses the three to five page research proposal the students are assigned in chapter fifteen of the Mills and Walter text, and, of course, the final product, the library research report, including the initial outline, the revised outline, and the progress report. The guide is particularly helpful on choice of topics, timing of assignments, and evaluation of the library research report.

In addition, the library is now preparing a student guide specifically for E346K-NST titled "Natural Sciences and Technology Research Guide for Junior Level Writing Course." It provides an overview of the library research assignment and sections on preliminary topic choice, background information, the research proposal, and the library research paper. For more information about this guide contact Nancy Ligrani, ECJ 1.300 (Pax 1813, Ctx 1610).

III. A Syllabus for E346K-NST Integrating a Maximum Number of Supplementary Texts

Because my primary aim is to demonstrate a range of supplementary texts that can make teaching E346K-NST attractive for traditional English teachers, a syllabus incorporating only one or two possible supplementary texts will not serve my purpose. Rather, what follows is a syllabus integrating a maximum number of supplementary texts. The aim is to show some relationships among the texts to be discussed instead of offering a model to be imitated point by point by all teachers of E346-NST. In any case, the latter seems particularly inappropriate for an upper-division course. The syllabus that follows would be appropriate to imitate only in a 346K section composed primarily of students from the life sciences probably, and even then would no doubt require too heavy a reading load. Hence the prospective teacher of E346K-NST is advised to select among the texts integrated in this syllabus and devote more time than is allowed here to the discussion of these texts in class.

The following syllabus not only has an unusually large number of supplementary texts, it includes four dates devoted to the showing of videotapes, all of which proved popular in pilot sections of this course taught 1981-1982. The videotape Einstein's Universe, starring Peter Ustinov and U.T.'s MacDonald Observatory and our own John Wheeler and Harlan Smith, was shown in the ninth week. A selection from the series The Voyage of Charles Darwin was shown in conjunction with the study of Darwin, and a NOVA videotape of the current state of genetic engineering was shown during the study of Watson, Crick, and DNA. Of course, many teachers may not want to use videotapes to this extent. The latter two tapes can easily be ignored in the syllabus, while a text by Einstein may be substituted for Einstein's Universe, as suggested in the syllabus. The Einstein text discussed here is the only supplementary text not tested out in one or more pilot sections for this course taught during 1981-1982, with the exception of the engineering texts briefly surveyed in section IV. F.

Suggestions about how different supplementary texts may be integrated into the course follow the sample syllabus. The particular sequence of assignments in the required text, Mills and Walter, is not meant to be prescriptive. It is important to remember, however, that students need to get started on their library research reports as soon as possible. Hence assignment of the chapters on interpretation and recommendation reports and research proposals in the first weeks was done in order to encourage students to write library research reports along these lines that will require some of the original thinking and creativity on their part which may be crucial for success in their careers. I then proceed to chapters twenty and twenty-one to give the students some idea of the physical appearance of the report they must write. The focus is then narrowed to chapter four on outlines and abstracts and chapter three on style. With the students now fairly well prepared to write their research reports, we can turn to special techniques of technical writing such as definition, classification, and description of mechanisms and processes. The latter, along with oral reports, may require more class time and thus are given more in the syllabus. Later, as we approach the deadline for the research proposal stage of the library research report, we focus on specific stylistic problems such as introductions, transitions, and conclusions.

In addition, Unit II begins with an example of a famous recommendation report whih is in some respects a useful stylistic model. The rest of unit II is in more chronological order. As much of the reading in supplementary texts happens to be in the biological sciences, a separate unit was devoted to that field as an example of a more detailed approach to one area of natural science and technology.

This syllabus is designed for a Tuesday-Thursday teaching schedule but is subdivided into weeks and thus may be adapted to a Monday, Wednesday, Friday schedule as well.

Symbols and Books Referred To.

For more information about these texts see section IV.

B = Bowen and Mazzeo, eds., Writing About Science

D = Appleman, ed., Darwin

E = Einstein, Relativity

M = Gordon Mills and John Walter, Technical Writing, 4th ed. New York: Holt, Rinehart, and Winston. 1978.

P = Pirsig, Zen and the Art of Motorcycle Maintenance

W = Watson, The Double Helix, ed. Stent

UNIT I: TECHNICAL WRITING, AND PIRSIG AS TIME ALLOWS: SIX WEEKS

WEEK ONE

Tu Introduction.

Th Writing the Library Research Report. M section 6, chs.22 & 23, pp.411-466; P chs. 1-3.

WEEK TWO

Tu Interpretation and Recommendation Reports. M ch. 9, pp.172-215; ch.14, pp. 261-272; P, chs. 4-7.

Th Research Proposals and Writing for Journals. M, ch.15, pp.273-291; ch.19, pp.359-367; P, chs. 8-11.

WEEK THREE

Tu Report formats and graphic aids. M, chs. 20&21, pp.371-410; John Walter and Ronald Stroud Technical Report Form; P, chs. 12-14.

Th Outlines and Abstracts. M, ch.4, pp.54-81, Appendix D, pp.518-526; P, chs. 15-18.

WEEK FOUR

Tu Style in Technical Writing. M, chs. 1-3, pp.1-51; check B199-200,206, 211,342 for jargon; P, chs.18-20.

Th Definition and Classification. M, chs. 5,8, pp.85-98,153-170; Identify examples of definition on B256-259,278,319,334-6 and D50-1; P, chs.21-24.

WEEK FIVE

Tu Description of Mechanisms and Processes. M, chs.6&7, pp.99-149.

Th Oral Reports. M, ch.17, pp.315-325; P, chs.25-27.

WEEK SIX

Tu Introductions, Transitions, Conclusions. M, chs.10-12, pp. 189-245; Research Proposal. M, p.291; P, chs.27-29.

Th Forms. Lab reports, progress reports, and business letters. M, chs. 13,16,18, pp. 247-260,292-314,326-357.

UNIT II. THE SCIENTIFIC ESSAY AND THE SCIENTIFIC METHOD: THREE WEEKS

WEEK SEVEN

Tu Hardin's Recommendation Report. B331-348.

Th Holton: Kepler and the Scientific Method. B307-330.

WEEK EIGHT

Tu The Beadles: Mendel and the Scientific Method. B274-286.

Th Feynman: Modern Physics and the Scientific Method. B219-237.

WEEK NINE

Tu Einstein and the Scientific Method. Einstein's Universe and/or E1-29, 38-86.

Th E instein and the Scientific Method. Einstein's Universe, pt.II and/or E100-114,123-124,135-157.

UNIT III. THE EXAMPLE OF THE BIOLOGICAL SCIENCES

WEEK TEN

Tu Wald, The Origin of Life. B287-306.

Th Darwin as Geologist. B236-252.

WEEK ELEVEN

Tu Darwin, The Origin of Species. D35, 44-131.

Th Darwin, The Descent of Man. D172-208.

WEEK TWELVE

Tu Millhauser, Loewenberg, Huxley; The Impact on Science I. D27-31,211-219, 244-256.

Th Huxley, The Impact on Science II. B253-273.

WEEK THIRTEEN

Tu Dewey, Randall, Chardin, Huxley, Simpson: Science, Philosophy, and Religion, D305-325,334-353.

Th Hofstadter, Kropotkin, Muller, Mead; Science and Society, D389-99,405-424.

WEEK FOURTEEN

Tu Stevenson, Krutch, Muller; Science and the Humanities, 513-526; Fleming, "Charles Darwin: The Anesthetic Man," from first edition of D.

Th The Double Helix, Wxi-70.

WEEK FIFTEEN

Tu The Double Helix, W71-133; Crick and Pauling, W137-152.

Th Lewontin, Bronowski, Merton, W185-7,200-203,213-218; Hardin, B199-218.

IV. SUPPLEMENTARY TEXTS

IV.A. Mary Elizabeth Bowen and Joseph A. Mazzeo, eds., Writing About Science, New York: Oxford University Press, 1979. 0-19-502476-1

If I were to choose a single supplementary text which gives examples of certain kinds of scientific writing and explores the social, ethical, and philosophical aspects of the disciplines, this would be the obvious choice. It is divided into two main sections, "Writing for Popular Audiences," and "Writing for Professional Audiences." I have restricted this syllabus to the latter section because it includes examples of the more technical writing styles which are the best source of examples for the Mills and Walter text. However, a teacher may well want to include some of the material by Faraday, Asimov, Russell, Thomas, Wiener, Eiseley and others in the first section, primarily because a good technical writer should be able to explain his subject to popular as well as professional audiences. Indeed, one of the students in my Spring 1982 pilot section for E346K was a graduate student in journalism preparing to be a science writer who naturally would have preferred much more reading in the first section.

In addition to this section, the anthology includes an introduction and a rhetorical table of contents which classifies the essays according to how well they exemplify definition; description; classificiation; enumeration; comparison and contrast; first person narration; narration and analysis of historical process; analysis of cause and effect; argument and persuasion; argument by example, by analogy, by personal experience; use of the imagination, of historical sources, and the work of other scientists.

I also found the "Professional Audiences" section useful for teaching the nature of the scientific method; the relationships between science, technology, religion, and the humanities; and specific subjects such as the role of emotion, personal pronouns, metaphor, and other "poetic" stylistic effects in scientific writing.

The Scientific Method. First of all, let us consider some of the ways the "Professional Audiences" section of Bowen and Mazzeo may serve as an effective supplement to the discussion of the scientific method in Mills and Walter (4). Let us take up the essays in the order in which they are presented in the syllabus (page numbers in parentheses).

Hardin's recommendation report (331-348) may be cited as a good example of logical and rhetorical progression of ideas, including argument by authority (331-2), examination of basic assumptions (331), meeting objections (332-3), qualifying (335), problem identification and proposal of solution (335), argument by example (337), and repetition of the argument (341).

Holton (307-330) reveals other aspects of scientific thought, namely, how the habit of presenting a rigorous structure in scientific rhetoric hides the actual steps of discovery and creativity (308), steps which include metaphor and analogy (308), the use of models (309,316), luck and intuition (313), error (315), rivalry (316), and interdisciplinary thought (317). At the same time, Holton identifies Kepler's devotion to reason (317), his capacity for concepts far removed from perception (321), how he relinquished ingrained preconceptions in the face of new quantitative experience (321) and thus initiated the modern scientific method.

The Beadles' essay on Mendel reinforces many of Holton's points. They contrast the myth of the cold, infallible scientist with the actual emotions and errors involved in scientific discovery and the rhetorical problems the creative scientist often faces when he tries to communicate his discoveries.

From the perspective of modern physics, Feynman is able to critique the myth of the infalliable scientist still more effectively. He establishes that science can not ultimately answer the question "why?" in all instances (219) and that a great scientist such as Newton may now be seen as simply wrong in some respects (225). He reveals that science must sometimes go beyond logic and accept paradox (225), inexactitude (226), an element of unpredictability (226), majority rule (227), "more or less" understanding (228), theories that are at least a little wrong (230), anomalies (233), and admission of ignorance (234-5). Feynman also emphasizes that words as well as numbers are needed in science (222).

Wald also makes a case for the importance of rhetoric in the history of science (289), for the possibility that scientists are the least sceptical of all judicious people (292), except when it is time to be sceptical of their own tendencies to special pleading (296). He also establishes the scientist's need to be objective, to get beyond our anthropocentric perspective (291).

Darwin on corals demonstrates the importance of theory and anomaly in science (237), deductive thought (239,241), hypotheses (243,245,246), and anticipating objections (249).

Huxley also illustrates the importance of listing the objections of one's opponents (253-5) and refuting them (255), especially by an appeal to logic (255) and objectivity (261-2), as well as the value of conceding points and qualifying one's claims where necessary (256,260).

Hardin's essay on DNA establishes the role of error in scientific progress (200,203) and the necessity of asking the wrong question at times (203).

Science and the Humanities. Hardin's DNA essay is perhaps more valuable as a source of connections between science and the humanities, especially between the discovery of DNA and the operation of language. Following information theory, Hardin stresses that information is non-material (201) and then demonstrates the importance of the rhetorical model by insisting that the message "is never an end in itself, but is always for the sake of something else" (203). He also uses information theory to illustrate the value of writing as a discipline (204). Hardin's "Tragedy of the Commons" essay makes clear the importance of the humanities from the outset in its basic thesis that there are many problems for which there are "no technical solutions" (331).

Huxley's defense of the humanities is still more explicit, especially in response to Haldane's charge that "when we speak of progress in Evolution we are already leaving the relatively firm ground of scientific objectivity for the shifting morass of human values." Huxley defends the objectivity of his approach yet insists that "as regards human progress, it is clear that subjective criteria cannot and should not be neglected; human values and feelings must be taken into account in deciding on the future aims for advance" (262,270,272). Huxley also includes "aesthetic creation and appreciation" as a sign of human progress (269-270). And of course the many allusions to works in the humanities by authors such as Hardin (204,335-6,339,341,343), Huxley (267-270), and Wald (298) demonstrate how scientists can incorporate their knowledge of the humanities in their work.

Even discussion of religion is included in some of the essays in Bowen and Mazzeo. Hardin (341), Huxley (271-2), and Wald (287-8), for example, criticize religion from the point of view of evolutionary science, but Holton emphasizes Kepler's synthesis of science and religion (309,316,322-330) and the Beadles discuss the problem of accepting something on "faith" in science in their discussion of the scientific breakthrough of an Augustinian monk, Mendel (285).

More specific issues which can be illustrated by these essays include revelation and even display of emotion by scientists, the use of personal pronouns, metaphor, rhetorical questions, effective transitions, and "poetic" effects in scientific prose.

Emotion in Science. The revelation of emotion ranges from the use of an exclamation mark to emphasize the author's emotion in Wald (291,295), Darwin (248), and in Hardin's "Tragedy of the Commons" (337), to Holton's discussion of Kepler's "intense emotional involvement" (308), ecstatic transport (320), and feeling of harmony (327). Wald finds beauty in cartilage and muscle tissue patterns (301), while Darwin expresses "unbounded astonishment" at lagoon islands (236), "truly wonderful structures" (239,245).

Personal Pronouns in Scientific Prose. If the myth of the cold, infallible scientist is shattered by such displays of emotion, the rule of writing invariably in impersonal, passive constructions in science is also put in doubt by the use of personal pronouns throughout Bowen and Mazzeo. The Beadles feel free to address the reader as "you" (274-5), as does Feynman (221) who also makes liberal use of "we" (220). The first word used by the greatest scientist in the collection, Darwin, is "I" (236) and he is not afraid of saying "I" repeatedly (246,248,251) along with "our" (246), a pronoun also favored by Wald (305).

Metaphor in Science. This more personal, more emotional approach to science is also more conducive to thinking in metaphor, it seems, for metaphor, the key to much of the knowledge of the humanities, pervades these essays. Perhaps the most thorough and significant demonstration of the crucial role of metamorphic thinking in science in this volume is Holton's account of Kepler's heavy reliance on analogues (308,322), models (309,316), archetypes (322) and the "fundamental image" (archetypische Bild)(324). Kepler's recurrent use of the clock metaphor (311,312,315,324) reveals the pattern of his archetypal thinking, but he was also capable of more anthropomorphic imagery, such as the image of the planets obsessed by magnetic forces (324). Yet Kepler remains aware of the limits of metaphors, at least those of others (312). Holton also cites metaphorical thinking in Copernicus (323) and Newton (308n) and himself makes effective use of metaphors such as "the inevitable astigmatism of our historical hindsight" and "unsuitable marshland" (308).

Perhaps the most fascinating of these essays in this respect for the teacher of English, however, will be Hardin's essay on DNA, for it consistently compares the function of DNA to human communication, speaking in terms of "letters" (206), punctuation (202), "message" (203,205), "reading" (203), along with a wealth of other metaphors such as Morse code (202), tape recording (202), spiral staircase (207), an architectural plan (208), "unsatisfied" bonds (211), and "daughter" molecules (213).

Feynman begins by demonstrating the crucial role played by a "fundamental image" of the world: "Before 1920 our world picture was something like this: the 'stage' on which the universe goes . . ." (219). He uses a scientific cliché such as "the machinery of interaction" (220), but proceeds to show that there "are no internal wheels" (226). Similarly, Feynman uses an extended analogy to develop the wave metaphor of electromagnetism (222-3), but shows its limits (224), along with the limits of a cliché such as "on the air" (223). He also makes very good use of personal analogy or anthropomorphism to explain how atoms "see inside" each other (220) and how a positive charge "feels a force" (222).

Hardin points out the limits of the "invisible hand" metaphor in his "Tragedy of the Commons" essay (335) yet makes effective use of pollution imagery (347). The Beadles also make good use of metaphor (275) as well as cliché (276-7). Wald analogizes photosynthesis to capitalism (304) and often refers to the organism as a machine (298,300), to architectonic tendencies in proteins (298-9,301), and to the sea as broth (299,301,302). He may well have been inspired by the progenitor of the biological sciences, Darwin, who described corals as "little architects" (244) and developed extended analogies to the growth of turf (238) and the constr-uction of a castle (240,242). In addition, Huxley considers the implications of taking for granted such metaphors as "higher" and "lower" (255) and whether or not our sense of progress is a "mere anthopomorphism" (261-2,271).

Many other rhetorical and poetic devices and effects could be illustrated, such as Kepler's assimilation of both poetry and prayer (308), the use of the term "strangeness" in modern physics (230), and the effective codas which conclude the essays by Wald (306) and Darwin (251). One could perhaps even go so far as to analyse the effectiveness of Huxley's use of alliteration, "These procedures would be almost laughable, if they were not lamentable" (255), or the "poetry" in a sentence of Darwin's such as "the whole line of reef has been converted into land; but usually a snow-white line of great breakers, with only here and there a low islet crowned with cocoa-nut trees, divides the dark heaving waters of the ocean from the light-green expanse of the lagoon-channel" (239).

IV.B. Albert Einstein, Relativity, The Special and General Theory, trans. Robert W. Lawson, New York: Crown, 1961. 0-517-025302

Like the Darwin text to be discussed next, this one gives students in the sciences and technologies a rare, perhaps their only chance to consult a primary text, in this case by the greatest scientific mind of this century, certainly in physics and astrophysics. Like Darwin before him, Einstein has become the paradigm of the scientist in his field, in this case the physical sciences. His own account of relativity reveals the essential features of the scientific method that made him so famous, along with his aesthetic sensibility, his sensitivity to words, his use of metaphor and personal pronouns, and his rhetorical awareness generally.

The Scientific Method. This text reveals Einstein's strong sense of the history and philosophy of science (see 136 on Descartes, for instance). Moreover, Einstein defines the usual sense of the progress "of an empirical science" as "a continuous process of induction," but emphasizes that "this point of view by no means embraces the whole of the actual process; for it slurs over the important part played by intuition and deductive thought in the development of an exact science" (123). Einstein is particularly conscious of what we might call the hermeneutics of science, the importance of "interpretation" of experimental results (53) and physical laws (65,68).

Einstein's emphasis on the role of theory in science is particularly obvious, including its heuristic value (43,63), especially for prediction (49,75). For him a theory may be a good one even if not justifiable by the current "facts" (51). His criteria for a good theory are that it should be "natural and simple" (19);

it should simplify the theoretic structure of the field (44); it should clarify (57); and it should suggest more hypotheses (75) and a more comprehensive theory (77,157). At one point he even prescribes what in techncial writing is called "standards of judgment" for a particular theory (101). Einstein's own theory of the connection between mass and energy is a good example not only of these particular features, but also that revolt against simplistic dualisms which is the essence of metaphor or, as he puts it, how "independent" laws "have been united into one law" (45-46).

His approach to experimentation seems still more unorthodox in the context of the traditional beliefs about empirical science in his day, for from the start it is obvious that his own experiments are but arm-chair thought experiements. Although at one point the translator refers to one of these as "this abstract experiment" (84), these experiments often seem more like sensory imaginings of "actual" cases (22). Nevertheless, if this represents a significant departure from the empirical sciences of Einstein's day, we should remember that in many respects he confirms the older scientific paradigm. For instance, like Darwin he admits difficulties in his theory (78) and is able to argue both sides of an issue (13).

Science and the Humanities. Einstein also recalls Darwin in his aesthetic as well as scientific response to his subject. For Einstein a theory can develop "in the most beautiful manner" (78); it can have "beautiful successes" (147); it can "excel . . . in beauty" (102); and it can have "great charm" (109).

In addition to this esthetic sensibility, Einstein has almost the sensitivity of a poet to the precise of meanings of such words as "true" (1-2), "position" (9), "space" (9,136-8), "world" (55,140), "time" (139ff.), "materialism" (142). Like an English professor teaching deeper awareness of words, at one point he makes a statement about lightning, asks a question about it, gets an initial answer to the question, and then says, "But if I approach you with the request to explain to me the sense of the statement more precisely, you find after some consideration that the answer to this question is not so easy as it appears at first sight" (21). Lightning is again the subject when he proceeds to give some answers himself. First he examines the meaning of such phrases as "calling to mind" and "recollection." Then he persuades us to change our interpretation of the phrase "'it is lightning' which originally entered the consciousness as an 'experience'" so that it "is now also interpreted as an (objective) event." He concludes: "It is just the sum total of all events that we mean when we speak of the 'real external world'" (140).

Personal Pronouns and Rhetorical Awareness. Despite the difficulty of the ideas he is trying to communicate, throughout the book Einstein maintains his awareness of the reader. The use of the personal pronoun and metaphor in the first sentence sets the tone for the whole book: "In your schooldays most of you who read this book made acquaintance with the noble building of Euclid's geometry, and you remember -- perhaps with more respect than love -- the magnificent structure, on the lofty staircase of which you were chased about for uncounted hours by conscientious teachers" (1). Einstein is very willing to speak directly of himself as "I," of the reader as "you," and to refer to both in terms of "we," "us," and "our." He can carry on a dialogue in these terms at some length and can even visualize the reader's reaction: "After further consideration you cast a somewhat disdainful glance at me" (23). He remains very much aware of the reader throughout the book, as he reveals in the opening of chapter twenty-three: "I would mention at the outset, that this matter lays no small claims on the patience and the power of abstraction of the reader" (79). Indeed, like the narrator of a Victorian novel he even humorously criticizes the reader -- "I am sure the reader will appreciate with sufficient clearness what I mean here by 'neighbouring' and by 'jumps' (if he is not too pedantic)" (83) -- and he anticipates the reader: "the reader may think that such a description of the world would be quite inadequate" (94); "Perhaps the reader will wonder why we have placed our 'beings' on a sphere" (111).

Metaphor. The first sentence of the book reveals not only Einstein's direct, personal, active voice, but also his love of metaphor. Metaphors and analogies are found throughout the book (9,55,57,64,76,99,114). Indeed, much of the revolution in physics in this century was based on the discovery of the limits of what turned out to be a metaphor: the aether and the aether-drift (52-53,146-147). One of Einstein's more important metaphors is "Translation" which is as important to him as it is to those who write about DNA (46). Crystallisation is another felicitous metaphor (49), and he devotes a whole page to an extended analogy with a gas range (72). More significant are his analogies between two and three dimensional universes (111), and between the motion of light and mechanical vibration (145).

IV. C. Philip Appleman, ed., Darwin, 2nd. ed. New York: W. W. Norton, 1979. 0-393-95009-3

If I were to choose a book of supplementary readings focusing on the work of a single great scientist which fully reveals the social, ethical, and philosophical aspects of science, I would choose the Norton Critical Edition, Darwin, now in its second edition. Both the first (1970) and the second (1979) editions are subdivided into the following sections: "I. Scientific Opinion in the Early Nineteenth Century"; "II. A Selection of Darwin's Work"; "III. Darwin and Science"; "IV. Darwin, Philosophy, and Theology"; "V. Darwin and Society"; and "VI. Darwin and the Literary Mind."

The second edition reduced the readings of Darwin's precursors but retained the essential summary, Milton Millhauser's "In the Air" (27-34 -- all page references to the second edition). Unfortunately, about forty pages of Darwin's own writings are cut in the second edition, but the 175 pages that remain should be enough to convey the essence of his writing style. Changes were made in the "Darwin and Science" section to make room for two new essays in the second edition: Richard Leakey's "The Greatest Revolution," which integrates evolutionary theory and archeology, paleoanthropology, geology, taphonomy, anthropology, animal behaviorism, and psychology, and Nicholas Wade's provocative essay relating evolutionary theory to the new gene-splicing techniques.

Section Four, "Darwin, Philosophy, and Theology," in the new edition retains the most important essays on philosophy and on Chardin's evolutionary mysticism and adds three new essays on the current debate between evolutionary science and creationism. Unfortunately, Theodore Roosevelt's controversial essay, "Biological Analogies in History" (1910) was dropped from section five, "Darwin and Society," but key essays are retained: Richard Hofstadter on Herbert Spencer, Peter Kropotkin's "Mutual Aid," and the highly controversial "Guidance of Human Evolution" by Hermann J. Muller, a professor at UT from 1920 to 1932. New in this section are Margaret Mead's reply to those who, like Muller, would attempt to engineer human evolution, and collections of essays on "Aggression and Altruism" and "Evolution and Intelligence." The former category includes provocative essays by Konrad Lorenz, Richard Leakey, and a debate between Edward O. Wilson and Stephen Jay Gould on sociobiology. The second category includes the Race-IQ controversy and essays by Jane Goodall, Carl Sagan, Naom Chomsky, and our own John C. Loehlin.

If some of these essays represent a further development of the social, ethical, and philosophical dimensions of science, the loss of Donald Fleming's brilliant "Charles Darwin, the Anesthetic Man" from the sixth section, "Darwin and the Literary Mind," was a blow to our sense of the relationship between science and the humanities. The reduction of this section from fifty-six pages to sixteen leaves it little more than an afterthought. Hence, as my sample syllabus suggests, I feel it is necessary to supplement this section of the second edition with Fleming's essay reproduced from the first edition.

In general the second edition remains an excellent interdisciplinary text. It is almost as relevant to the new "Social and Behavioral Sciences" version of E346K as it is to the "Natural Sciences and Technologies" version, for it includes the writing of anthropologists (Margaret Mead, J. N. Spuhler, Richard Leakey, Roger Lewin), psychologists (John C. Loehlin, Gardner Lindzey, Richard Herrnstein), a linguist (Naom Chomsky), and some of the founders of sociology (Herbert Spencer) and sociobiology (Edward Wilson). A truly interdisciplinary text such as this could be used not only in courses explicitly devoted to writing for students in other disciplines than English, but in many other kinds of writing courses as well, I believe. Texts like this may also be of some use in other courses in composition in the upper division, in lower-division courses in expository writing which include an introduction to logic, and of course in technical writing courses which include some students in the life sciences.

I would go further myself, suggesting that we consider redefining "literature" in humanities departments to mean what it meant for Matthew Arnold a century ago -- the best writing in all disciplines, including the seminal texts in the history of science. Hence one could argue for some interdisciplinary emphasis even in those writing courses which focus primarily on "literature" such as E603, "Composition and Reading in World Literature."

In E346K-NST Darwin enables us to carry on the discussion from the essays in Bowen and Mazzeo and from Einstein's Relativity on the scientific method and the relations between science, the humanities, and religion, as well as such specific issues as the role of emotion, personal pronouns, metaphor, "poetic" writing in science and other aspects of scientific rhetoric.

The Scientific Method. Like Einstein's Relativity, the selection from Darwin's writings enables students in the sciences and in engineering to do what they rarely get a chance to do: put aside their "textbooks" and look at the actual text, the writing of one of the three or four greatest scientists in the history of the world. They can see for themselves the shift from Newton to Darwin analysed by Randall (320-321). This provides an opportunity to introduce T. S. Kuhn's The Structure of Scientific Revolutions which reveals the key role played by rhetoric in paradigm change in science. They can thus go to the source itself, to the paradigm of the biological sciences, and find specific page references for and ask their own questions about Darwin's relative emphases on facts, details, evidence, observation, experiment, hypotheses, reason, subjectivity and objectivity, falsifiability, induction, deduction, classification, definition, structures, systems, theory, laws, environmental determinism, ideas of unity, universality, and meaning in the universe; Darwin's use of mathematics and metaphor; his arguments by cause-and-effect, by analogy, by authority; his confessions of ignorance, limited knowledge, and potential for error; his ability to argue both sides of an issue; and his explicit references to the "scientific point of view." Chapter fifteen of the Origin (108-131) alone illustrates almost all of these features.

Science and the Humanities. If Darwin allows us to see the scientific method at work, it also reveals many important connections with the humanities. It is particularly useful for generating basic questions about the relationship between the sciences and the humanities which resist pat or easy answers such as in what respects may a scientist as a scientist cultivate or even rely on his or her sense of beauty, sublimity, or nobility? The connections between verbal art and science in Darwin encourages us to ask, what is the relation between reason and imagination in science? How important is a command of language for a scientist? How essential is rhetoric, metaphor, and style to the success of a new scientific theory?

Of course many other questions which reveal social, ethical, or philosophical dimensions of science are also prompted by Darwin's theories such as, Is the world and all its objects and events the product of blind chance? Can language express this possibility? Or is the universe basically purposive, advancing, progressing in organization and complexity, toward perfection? Is man the zenith of evolutionary development? What do we make of neutral changes or reverses and reversions in evolutionary history? What is the relation between the past and the present? Is the past unique and nonreturning? If so, is the present endlessly new, constantly creating a sense of futurity? Can we control the future by understanding the past? Must we shift our minds from contemplation of timeless, static realms to plunge into the shifting, relativistic flux of the present?

Darwin also generates basic questions about a scientist's relationship with his culture such as to what extent is a scientist and his science inevitably a product of his culture? For example, does a biologist's emphasis on competition or on cooperation in nature reflect his own society as much as his objective discoveries? If so, how do we determine objectively to what extent success in nature is due to individual competition or to mutual aid?

In addition to generating such basic questions, Darwin reveals the highly developed aesthetic sense evident in Darwin's admiration for "perfection of structure" (36), "exquisite adaptations" (49), "beauty and complexity of the co-adaptations" (71) and "really wondrous and beautiful organization" (84) throughout The Origin of Species. Moreover, The Descent of Man discusses man's social habits, "appreciation of the beautiful" (206), "moral faculties" (201), "remorse" (178), "sympathy and the love of his fellows" (175).

Darwin's "bulldog," Thomas Henry Huxley, also discussed such issues as "intellectual sublimity" and "esthetic intuition" in "On the Relations of Man to the Lower Animals" (231-241). In addition to these primary texts, Darwin includes much about the influence of the humanities on Darwin's development and the influence of his theories on the humanities. Sir Gavin de Beer's "Biology Before the Beagle" (3-10) includes French philosophers and Millhauser discusses many other pre-Darwinian philosophers and writers. Morse Peckham turns to Darwin's impact on his literary contemporaries and to the relationships between the sciences and the humanities generally in his essay, "Darwinism and Darwinisticism" (297-305). Specific connections between Darwin and philosophy are explored in detail in John Dewey's "Influence of Darwin on Philosophy" (305-314), John Herman Randall's "The Changing Impact of Darwin on Philosophy" (314-325), Thomas Henry Huxley's "Evolution and Ethics" (325-328) and Sir Julian Huxley's "Evolutionary Ethics" (328-334).

The large section, "Darwin and Society" (389-510), reveals many connections between Darwin and the human sciences. The essays of Lionel Stevenson, Joseph Wood Krutch, and Herbert J. Muller collected in the section "Darwin and the Literary Mind" (513-529) and Philip Appleman's epilogue, "Darwin: On Changing the Mind" (529-551) document Darwin's influence on literature, although, as I have said, they are more effective if supplemented by Donald Fleming's brilliant summary of Darwin's personal response to the humanities, "Charles Darwin the Anesthetic Man" from the first edition.

Science and Religion. In a number of respects the relation between the sciences and religion is a larger issue in Darwin than the relation between the sciences and the humanities. Darwin himself discusses the relationships between his theory and religion in The Origin of Species and in The Descent of Man. The latter also discusses the tendency toward religious belief in man generally. Some of the important pre-Darwinian theologians are also cited in Darwin. De Beer mentions William Paley; Millhauser includes John Henry Newman and the German "higher criticism" of the Bible; Appleman discusses Paley and less familiar religious figures of Darwin's youth. Bert James Loewenberg focuses on the theological dimensions of Darwin's debate with scientists such as Charles Lyell and Asa Gray in "The Mosaic of Darwinian Thought" (211-220), but perhaps the best discussion of Darwin and religion remains Fleming's essay in the first edition.

Andrew Dickson White provides a summary of the theological resistance to Darwin's theories in the nineteenth century (362-368). Darwin's influence on religion in this century is discussed from several perspectives in Darwin. A brief selection from Pierre Teilhard de Chardin's attempted synthesis of evolutionary science and Christianity, The Phenomenon of Man (334-342), is followed by three scientists' views of him: Julian Huxley's introduction to Chardin's book (342-346), George Gaylord Simpson's "Evolutionary Theology: the New Mysticism" (346-353) and Peter Medawar's review (353-362). The most recent development in the debate between science and religion is of course the rise of a new rival, "scientific creationism," and it is criticized in Preston Cloud's "'Scientific Creationism' -- A New Inquisition Brewing?" (368-382) and in several statements signed by various scientists (382-386).

Science, Emotion, and Personal Pronouns. Darwin's response to religion is but one of many of his emotions discussed in Fleming's essay. Other direct revelations of his emotions are evident in the selection of his letters which, like the Fleming essay, was dropped in the second edition. Nevertheless, Darwin's style still conveys his emotion as well as his scientific method. A sense of humor may be detected at times (179) and he uses "I" and "my" quite liberally. Indeed, the autobiographical impulse is evident from the outset in The Descent: "The nature of the following work will be best understood by a brief account of how it came to be written. During many years I collected notes . . . " (132). Incidentally, Chardin makes an issue of the use of the "I" and the dichotomy between the personal and the impersonal.

Metaphor. Another fascinating aspect of Darwin's style is his use of and attitude toward metaphor. Darwin is quite conscious of the advantages and disadvantages of metaphor. Consider, for instance, the use of the term "struggle for existence": "I should premise that I use this term in a large and metaphorical sense" (50). He discusses the metaphorical implications of the term "Natural Selection" explicitly at some length (54-55,57) and the implications of his personification, "Nature" (56). Darwin himself is a master of metaphor as we see in his tree simile (87), his metaphor of the museum (130) and in hundreds of other examples. Nevertheless, he imagined a time when all scientific terms "will cease to be metaphorical and will have plain signification" (129). Hence his texts present us with an excellent opportunity to discuss the role of metaphor in scientific writing.

Style and Rhetoric in Scientific Writing. The importance of style generally in scientific rhetoric is obvious in Darwin. Millhauser points out how science reached the public through skilled expositors such as Lyell. In many respects Darwin was the most skilled of all, always conscius of the reader, as in Chapter III of The Descent: "I shall arrange my remarks in the order most convenient for my purpose; and will select those facts which have struck me most, with the hope that they may produce some effect on the reader" (177). Later Darwin defines "the half-art and half-instinct of language" (199) and one can be sure he was quite conscious of that portion which was "half-art."

He is a master of the use of vivid, convincing examples, effective summaries, direct addresses to the reader, rhetorical questions (often in series), long lists and catalogues, and elaborate parallelism to construct a long, concluding sentence (as on 50). Concluding codas like this one are often quite beautiful as well as effective, especially the tree simile (87), and the conclusions of the Origin (131) and the Descent (208). Sometimes the beauty of the codas may be traced to alliteration as well as to the sublimity of the thought, as in chapter ten of the Origin: "Therefore a man should examine for himself the great pile of superimposed strata and watch the rivulets bringing down mud, and the waves wearing away the sea-cliffs, in order to comprehend something about the duration of past time, the monument of which we see all around us" (106).

IV. D. James Watson, The Double Helix, A Personal Account of the Discovery of The Structure of DNA, ed. Gunther S. Stent. New York: W. W. Norton, 1980. 0-393-95075-1.

The Norton Critical Edition of the discovery of DNA does not include the wide range of supplementary essays that the Norton Darwin has, nor is the primary text involved as obviously scientific writing as Relativity, The Origin of Species, or The Descent of Man. Yet the Norton Double Helix has a number of advantages. Like Relativity, it is relatively brief and Watson is even more contemporary than Einstein. In addition, it has a number of valuable supplementary essays and provides opportunities to discuss the scientific method, technical writing, metaphor, and the relation between the sciences and the humanities generally.

The Norton Critical Edition consists of an introduction by Gunther Stent on DNA, the rise of molecular biology, Watson, and the publication of The Double Helix. Also included in the introduction is Walter Sullivan's review, "A Book that Couldn't Go to Harvard." The text of the Double Helix itself is 133 pages. It is followed by three other perspectives on the discovery of DNA, those of Francis Crick (137-145), Linus Pauling (146-152) and Rosalind Franklin (153-160). The fourth section consists of the reviews of the book, all from 1968, by Philip Morrison, F. X. S., Richard Lewontin, Mary Ellmann, Robert Sinsheimer, John Lear, Alex Comfort, Jacob Bronowski, Conrad Waddington, Robert Merton, Peter Medawar, and André Lwoff. Also included in this section are Stent's summary of the reviews (161-175) and three letters to the editor of Science in 1969. The fifth and final section collects six of the original technical papers announcing the discovery of DNA.

Scientific Method. Watson's discovery should not be underestimated. Darwin was the great pioneer of the biological sciences, but Watson and Crick's discovery was, according to Peter Medawar, the "greatest achievement in science in the twentieth century" (220). Hence Watson and Crick are almost as important as exemplars of the scientific method in this century as Darwin was in his. Yet, as Stent points out, they reveal that "feelings, social interactions, and irrational attitudes" have "a much more prominent role in the advancement of knowledge" than we thought (ix). The belief in pure objectivity in science, in "disembodied intellects" (16,17,213), is challenged. As Philip Morrison put it in his review, "The Human Factor in a Science First," this "story should kill the myth that great science must be cold, impersonal, detached" (177). Richard Lewontin announces "the fact that scientists, like other artists, are intensely emotional" and proceeds to argue that The Double Helix is the scientific counterpart of Francoise Gilot's Life with Picasso (185). Even facts may no longer be regarded as "objective givens" but rather considered as "thought collectives" (ix). As Watson puts it, "science seldom proceeds in the straightforward logical manner imagined by outsiders. Instead, its leaps forward (and sometimes backward) are often very human events in which personalities and cultural traditions play major roles" (3). According to Crick, "it is partly a matter of luck and partly good judgment, inspiration and persistent application" (145).

In his account of Rosalind Franklin, Aaron Klug also stresses that "there was no inexorable logic" (156) leading them on, a phrase echoed by Merton (213) and Stent (16,17). As a result, "no beginner in science will henceforward believe that discovery is bound to come his way if only he practices a certain Method" (174,224). As Bronowski puts it, Watson's "book communicates the spirit of science as no formal account has ever done," revealing "how the scientific mind really works: that we invent a model and then test its consequences, and that it is this conjunction of imagination and realism that constitutes the inductive method" (203, cf.167,xx).

Technical Writing. Scientific writing per se is discussed explicitly on a number of occasions throughout the text. For instance, Crick considers Stent's argument that "a scientific discovery is more akin to a work of art than is generally admitted. Style, he argues, is as important as content" (144). Yet style is a problem for scientists according to Erwin Chargaff, for scientists "often do not know how to write" (169). Part of the problem may be the discrepancy between the scientific method as conveyed in scientific rhetoric and as it is actually practised; in this context Robert Merton cites Francis Bacon's complaint that "never any knowledge was delivered in the same order it was invented" (213).

Watson provides a number of wonderfully frank critiques of technical or scientific writing in his story of the discovery of DNA, including his account of "the painful reading of professional journals" (32) and his reference to the work of J. D. Bernal and I. Frankuchen: "I was unable to understand large sections of their classic paper" (67). He had a similar response to an article by Linus Pauling: "most of the language was above me, and so I could only get a general impression of his argument. I had no way of judging whether it made sense" (25). Nor was this problem unique to himself, as his comment on Joshua Lederberg suggests, "Only Joshua took enjoyment from the rabbinical complexity shrouding his recent papers. Occasionally I would try to plow through one, but inevitably I'd get stuck and put it aside for another day" (83). He reveals similar problems with scientific papers delivered in person (22-23). When we consider that these comments were made by a Nobel Prize winner, one of the most creative scientists of the century, they clearly pose questions that can provoke useful class discussion and heighten student awareness of the role of rhetoric in science.

Particularly useful is analysis of the six original papers included in the Norton Critical Edition. Crick himself compares the styles and strategies of the first two papers by Watson and himself, focusing on the omissions in the first paper, its muted tone, and the fact that "a casual reader could easily have overlooked the significance of the first set of papers, especially as they were full of obscure crystallographic jargon" (139).

Science and the Humanities. In addition to these practical connections between science and writing, the larger issues of the relations between the two cultures, the sciences and the humanities, may also be discussed in the context of this book. Like Darwin and Einstein, Watson and Crick clearly have aesthetic sensibilities, for instance. Watson described their idea as "aesthetically elegant . . . telling each other that a structure this pretty just had to exist" (120, cf.124). Crick praises "the instrinsic beauty of the DNA double helix. It is the molecule which has style, quite as much as the scientists" (144).

In his review of the reviews Stent cites Sinsheimer on "the humane and esthetic qualities of science" (164,194); Bronowski's suggestion that Watson played Boswell to Crick's Dr. Johnson (167,202); Bronowski on how Watson and Crick fit into the contemporary literary scene (167,203); Waddington's comparison of Watson and Salvador Dali (167,205); Chargaff's comparison between Watson and Sterne (169); and Chargaff's contrast between scientific autobiography and the art of Shakespeare and Picasso (170). In addition Stent praises the interdisciplinary achievement of a writer also included in the Norton Darwin: "Peter Medawar, one of our few contemporaries who has made scientific contributions of the first magnitude while at the same time possessing considerable philosophical and literary skills" (172).

Other connections with the humanities are also apparent in the reviews such as Medawar's discussion of the "literary structure" of The Double Helix (223). Comfort feels that Watson has "the panache of a brilliant novelist" (199), while Bronowski argues that "this story of a great and beautiful discovery" (202) is more in the genre of a "classical fable" (201). Robert Merton focuses on the role of "taste" in science (216) and suggests still another literary genre in his reference to "Watson's Apologia Pro Vita Sua" (218). All of these connections lead up to Stent's question, "to what higher achievement can one aspire after having been anointed as a Great Scientist? To make it as a Great Writer" (163).

Metaphor. Specific "literary" issues such as the role of metaphor may also be explored in this text. The great metaphor of DNA as language, for instance, is as evident in Stent's introduction (xviii-xix) as it is in Hardin's essay in Bowen and Mazzeo. Indeed, metaphorical thinking pervades the Norton edition of Watson, from Stent's allusion to Kékulé's vision of the benzene ring as a snake biting its own tail in his introduction (ix) to Merton's citation of Clerk Maxwell's letter to William Thompson: "I do not know the Game Laws and Patent laws of science . . . but I certainly intend to poach among your electrical images" (215). The allusion to Maxwell presents us with an excellent opportunity to introduce Max Black's theory of the role of metaphor in the sciences and the humanities, for Maxwell is one of his primary examples. As Black points out, the term is often "analogue model" rather than metaphor in the sciences, but the concepts are obviously related. Darwin often argued by "analogy" rather than metaphor and Pauling lectured on "analogies between antibodies and simpler chemical substances" (148). But of course the primary term for Watson and Crick was "model" and it too can be extended to cover all metaphorical thinking if we realize that, say, Einstein's "space-time is a model, and so is every discovery," as Bronowski put it in his review, "Honest Jim and the Tinker Toy Model" (203). Watson himself compared his molecular models to "the toys of preschool children" (34) and Crick mentions their "persistent propoaganda for model building" (144). Even Rosalind Franklin took up model-building (155) according to Klug, and Merton stresses how they needed the help of Franklin and others "to do the job of imaginative scientific carpentry that led to their momentous model" (216).

Moreover, the larger issue of the revolt against simplistic dualisms, of which metaphor is but one instance, is developed fairly extensively in the Norton edition of Watson's story. Complementarity, for example is one of the dominant modes of transcending simplistic dichotomies in modern physics, and hence we should not be surprised that Watson and Crick call theirs "the Complementary Model" (264-267). "Complementary structures" is also a normative word in Linus Pauling's "Molecular Basis of Biological Specificity" (147-8, 150).

Interdisciplinary thought itself is an instance of the transcendence of dualistic structures, of course, and it pervades the Norton Edition of Watson: in the account of how Watson and Crick introduced genetic reasoning into structural determination (xvii), in Stent's own interdisciplinary metaphors (xviii-xx), in the combination of x-ray crystallography and molecular biology discussed by Crick (141), in Alex Comfort's review, "Two Cultures No More" (198-200), and in our realization that Watson's book itself is an interaction between the fields of science and literature.

IV. E. Robert M. Pirsig, _Zen and the Art of Motorcycle Maintenance, An Inquiry into Values_. New York: Bantam, 1975. (chapter numbers rather than page numbers given because page numbers vary with different printings)

No doubt this text will seem the most controversial possibility for a supplementary text in E346K-NST because some consider this a novel. However, all available information and the author's note suggest that this may just as well be considered in the same genre as _The Double Helix_, namely autobiography: "what follows is based on actual occurrences. Although much as been changed for rhetorical purposes, it must be regarded in its essence as fact." In fact, if _The Double Helix_ is the autobiography of a scientist, this is the autobiography of a technical writer, for that was Pirsig's occupation. Indeed, this book began as an eight-page essay on technical writing submitted for the Modern Language Association convention of 1969.

Hence we should not be surprised to discover that a number of papers have already been written on the relevance of this book for the teaching of composition, including Paul Sorrentino's "Using Pirsig's _Zen and the Art of Motorcycle Maintenance_ to Teach the Nature of Objectivity in Scientific and Technical Writing" and Mary Oates' "Vroom at the Bottom: _Zen_ and the Art of English Composition."

Even if one insists that this is an autobiographical novel there are good grounds for including it in a course such as E346K-NST which is supposed to make students aware of the social, ethical, and philosophical aspects of science as well as teach them technical writing. The American Association for the Advancement of the Humanities revealed that "popular novels are being used increasingly to bring an awareness and understanding of the humanities to community and junior college students in occupational and technical programs. Novels appear to succeed in relating the working world to the study of values where abstract disciplines fail" (_Humanities Report_, III:10, Oct., 1981, 9-12). Pirsig's subtitle suggests the special relevance of this book for this purpose.

In addition to raising student consciousness about the relevance of values to science and technology, Pirsig's book includes explicit analyses of technical writing and, unlike the other texts we have considered, discusses technology at length as well as science, and, like the other texts we have considered, provides opportunities to discuss the scientific method, objectivity, the relations between science, the humanities, and religion, and specific issues such as the role of metaphor in scientific thought.

Technical Writing. An example of technical writing is discussed in chapter six, for example, in which the analytical technique of "partition" is applied to a motorcycle. In addition, an outline articulating the relation of the parts is produced (ch. 8). Pirsig's narrator then proceeds to analyze the analysis, pointing out how people from the humanities will find it "dull, awkward, and ugly," will notice that immediate surface impressions are missing, that "no value judgments have been expressed anywhere, only facts," and will see how easy it is to assume that this is the only possible format for analysis. Chapter fourteen takes up again what to the English teacher seems to be the "ugly, chopped-up, grotesque sentence style common to engineering and technical writing" and why an artist might condemn it for "the lack of artistic continuity, something an engineer couldn't care less about." Focusing on some instructions for assembling an outdoor barbecue rotisserie, one complaint concerns the "format" again: "Technology presumes there is just one right way to do things and there never is." Further discussion leads to the provocative conclusion that the "divorce of art from technology is completely unnatural . . . . Rotisserie assembly is actually a long-lost branch of sculpture, so divorced from its roots by centuries of wrong turns that just to associate the two sounds ludicrous."

Scientific Method. The narrator's ultimate solution is to "expand the nature of rationality" and thus, like the other texts, Pirsig's discusses the scientific method. Logic is defined in chapter seven, and the history, steps, and purpose of the scientific method is discussed at length in chapter nine. The second of the six steps, generation of "hypotheses as to the cause of the problem" receives special attention. Einstein is cited in chapter ten on "intuition" and "sympathetic understanding of experience" as a source of hypotheses about the laws of the cosmos. By the time we get to chapter sixteen we are prepared for the statement, "For every fact there is an infinity of hypotheses. The more you look the more you see," an idea explored in more detail in the discussion of Poincaré in chapter twenty-two. The names "Einstein" and "Poincaré" help introduce the subject of the temporality or relativity of scientific knowledge in chapters ten and twenty-two, respectively. Philosophical critiques of basic assumptions of causation, time, and space follow the introduction of Einstein in chapter eleven. The limitations of binary thought in particular are emphasized throughout the book but perhaps most effectively in chapter twenty-six.

Science, Technology, and the Humanities. One of the specific dualisms discussed at length throughout the book is technology vs. the anti-technological feelings and protests of modern America, especially in chapters one, two, five, and six. Chapter six expands the discussion to include the simplistic dichotomy between science and technology, on the other hand, and art and the humanities, on the other. Chapter seven continues this discussion and adds another ingredient to the arts and humanities mix -- Eastern religion -- which is discussed again in chapters twelve, sixteen, seventeen, twenty-one, twenty-two, twenty-five, twenty-six, and twenty-nine.

Personal Pronouns. Still another important dualism is that of subject vs. object, observer vs. observed, which is a different way to describe the problem of the use of personal vs. impersonal pronouns, active vs. passive voice in technical writing. The second feature discussed about technical writing in chapter six was that the "observer is missing." This issue is taken up in more detail in the discussion of the rotisserie assembly instructions in chapter fourteen, where its relevance to the maintenance of machinery and art is established. In chapter twenty-four the problem of a stuck screw provokes the whole issue of objectivity again and the difference between a good mechanic and a bad one.

Finally, in chapter twenty-six the narrator makes his famous statement, "the real cycle you're working on is a cycle called yourself" and he goes on to explore the relationship of the subject-object dualism to anti-technological feeling in America in chapter twenty-nine. The importance of transcending the simplistic subject-object dualism in science as well as technology is demonstrated in chapters three and nineteen, among others.

Metaphor. Many other specific issues could be illustrated in Pirsig's book, but the transcendence of simplistic dualisms through metaphor will serve as a final example. The reader and the protagonist work their way toward the discovery of the eventual oneness of the world and discover that "The One can only be described allegorically, through the use of analogy, of figures of imagination and speech" (ch.30). They move toward this discovery by a series of revolts against dualisms, both directly by rational discussion of dichotomies and related topics and indirectly by increasing reliance on metaphor as a mode of communication and thought.

The increasing reliance on metaphor requires students of E346-NST to develop their own capacities for metaphor. One of the first simplistic dualisms to be rejected is that between "ghosts" and "the laws of science," between "primitive" or "medieval" thought and science, the primary example being the law of gravity (ch.3). Soon afterwards the "ghost" motif returns, initiating the recurring metaphor of Phaedrus, implying a comparison to the protagonist's prior self as well as to the two horses of the chariot of the soul in Plato's Phaedrus. Later the protagonist focuses on the simplistic dualism of the two "horses" or motorcycles in the journey, his and John's, and sees that each of them has a valid "vision of reality" though they seem to conflict (ch.5). Chapter seven introduces another metaphorical valence of "Phaedrus" -- the "wolf" -- and it is explicitly compared to the speaker's alter ego.

Such metaphorical connections are given a boost when, in chapter ten, a 1918 speech of Einstein's is introduced into the text which is, among other things, densely metaphorical. Two of the most important metaphors are "the temple of science which has many mansions" and "the high mountains" of the mind. As Relativity suggests, it is perhaps no accident that Einstein, who led the modern revolt against simplistic dualisms with his rejection of the absolute dichotomy of energy and matter, was also attracted to metaphor.

One of the central metaphors of the novel recurs in the next chapter, that of Phaedrus, the uncaged, wild, devouring ghost of impersonal rationality, but the synthesis stage in the Hegelian dialectic of this book soon reasserts itself in Northrop's discussion of the union of the theoretic and the esthetic, the Western and the Oriental (ch. 11). The dialectic becomes metaphorical again in the reference to the "thinning air of uncertainty" in "the high country of the mind" (ch.11), no doubt an allusion to Heisenberg as well as Einstein. This imagery of the landscape of the mind then becomes particularly striking in chapter fourteen. Finally, in the opening pages of Part III, the speaker reveals that he has indeed been providing the reader with an allegory, an allegory akin to the religious allegories in Zen Buddhism and in "the tales of every major religion," including those of Jesus and Moses. He soon invokes a "cathedral effect" of light in the pines (ch.16), an image which recurs in a way at the end of chapter nineteen.

Eventually the protagonist realizes that creativity is virtually antithetical to absolute dualisms (ch.24) and he begins to explicitly reject simplistic dichotomies between subject and object, scientific and esthetic (ch.24). He also finds beauty in math (ch.22) and in technology (ch.25). At this point, if not before, the reader becomes aware that the primary "message" of this text was conveyed through its metaphors and presumably the reader begins to become more aware of their significance, especially the landscape of the mind in the concluding pages of the book.

IV. F. Supplementary Texts for Engineers.

Engineering students have to take many science courses and engineering is often thought of as applied science. Thus we can assume that engineering students in E346K-NST will have a natural interest in the supplementary texts in the sciences that we have already discussed. They will be particularly interested in Einstein and Feynman, because they are required to take courses in physics, and in Pirsig, because he talks a good deal about technology. They may also be able to relate to, say, the NOVA videotape on genetic engineering, if only because the research is conducted by companies which patent their products. However, supplementary texts in the life sciences will seem more remote from their interests.

In fact a case may be made that an engineer is someone quite different from a scientist, not merely from a scientist like Darwin or Watson, but even a scientist like Einstein or Feynman. "Engineers are not . . . primarily scientists," as one engineer put it: "If they must be classified, they may be considered more humanists than scientists. Those who devote their life to engineering are likely to find themselves in contact with almost every phase of human activity. Not only must they make important decisions about mere mechanical outline of structures and machines, but they are also confronted with the problems of human reactions to environment and are constantly involved in problems of law, economics, and sociology. . . The work of the engineer is by nature synthetic. . . . It consists of putting together fragments from human relations, from science, from art, from craftmanship to produce new assemblages" (Hardy Cross, <u>Engineers and Ivory Towers</u>, New York: McGraw Hill, 1952, pp. 5-6).

Thus we need to give some attention to the large numbers of engineering students who will be taking E346K-NST. Most students in my sections of E317 have been in engineering, partly because of the way requirements are set up in various colleges, and we can expect engineering students to continue to make up a large percentage of students in E346K-NST. No doubt they would benefit from the inclusion of one or two supplementary texts addressed directly to them.

A book for engineers comparable in many respects to the Bowen and Mazzeo collection is Engineers as Writers, edited by Walter Miller and Leo Saidla (New York: Van Nostrand, 1953, Engineering Library Call No. 620.09 M619e). This is a collection of outstanding writing by engineers from ancient Rome to the 1950's. It includes an introductory essay on writing in engineering and for each author provides an introduction, critical comments, and suggestions for further study in an English course. The editors, both Professors of English, point out many features comparable to those we have discussed in the supplementary texts in the sciences, including the scientific attitude, emotion, the social dimensions of engineering, the relation between engineering and various aspects of the humanities, the use of metaphor, simile, and analogy, personal pronouns, the active voice, and other stylistic features such as parallelism, periodic sentences, contrast, and antithesis.

Other anthologies are available, especially on the subject of engineering and society, but I know of no others that include such a high proportion of writing by engineers themselves. However, one text does devote half of its space to writing by engineers and half to "humanists": William Davenport's and Daniel Rosenthal's Engineering: Its Role and Function in Human Society (New York: Pergamon, 1967, Engineering Library Call No. 620 D278e). This is very good on the social dimension of engineering, particularly on hostility to and acceptance of technology in society and ways to bridge the gap between engineering and the humanities. It includes essays by John Henry Newman, Samuel

Butler, Henry Adams, Aldous Huxley, Herbert Hoover, Lynn White, Norbert Wiener, Vance Packard, Rachel Carson, and Eric Severeid. A popular paperback anthology along the same lines is Technology and Man's Future, edited by Albert Teich (3rd ed., New York: St. Martin's, 1981, ISBN No. 0-312-78996-3), but writing by engineers is not well represented. It includes selections from Robert S. Morrison, Buckminster Fuller, Robert Pirsig, and Paul Goodman, among others.

Supplementary texts by individual writers are also available for engineering as well as science majors. One of the most successful and provocative texts is Samuel Florman's The Existential Pleasures of Engineering (New York: St. Martin's, 1976, Engineering Library Call No. T 14 56). Like Engineers as Writers, this book will give the teacher of E346K-NST a sense of how engineers think, but it also gives an extended account of how they feel. What Florman means by "existential" is "(1) rejection of dogma -- particularly scientific dogma; and (2) reliance on the passions, impulses, urges, and intuitions that are the basic ground of our personal existence" (xi). The social, ethical, and philosophical dimensions of engineering are very clearly spelled out. He includes a history of engineering and various responses to aspects of it by Kipling, Strindberg, Wells, Whitman, Sandburg, Robert Louis Stevenson, Henry Adams and others. "The Golden Age of engineering from 1850 to 1950" is discussed, along with the successes and criticisms of technology during the environmental crisis and the antitechnological movements of the last few decades. Florman then proceeds to offer "a new philosophy of engineering" to replace the naiveté with which engineers have approached the social dimensions of their subject in the past and he effectively defends the engineer from the attacks of the "antitechnologists." In short, Florman is an effective example of an eloquent and literate engineer and his passionate arguments are a good source for class discussions.

He has also written Engineering and the Liberal Arts: A Technologist's Guide to History, Literature, Philosophy, Art and Music (New York: McGraw-Hill, 1968, Engineering Library Call No. 001.3 F665e). He provides introductions for engineers to the fields mentioned in his title. As his introduction to literature, for example, he has a chapter on the engineer as protagonist in the fiction of Kipling, Cather, Mann, Golding, Hersey, and Michener, among others, and a chapter briefly surveying world literature. Besides Florman, other examples of individual engineers who write are available, such as Eldred Harrington's An Engineer Writes About People, Places, and Projects (Albuquerque: Calvin Horn, 1967, Engineering Library Call No. 620.4 H237e) which includes "Adventures into Engineering History," but Florman is one of the best possibilities for a supplementary text.

Another way to get the attention of engineering students is to focus on one of the standard topics of rhetoric, invention, and include something about creativity in engineering. Engineering teachers are concerned about fostering creativity in their students, as Herman Estrin's Higher Education in Engineering and Science makes clear, and a book such as Robert Bailey's Disciplined Creativity for Engineers (Ann Arbor: Ann Arbor Science, 1978, Engineering Library Call No. TA 153 B25) relates creativity in engineering to emotion, sensitivity, values, philosophy, esthetics, intuition, and the unconscious.

V. Conclusion.

Other texts will occur to other teachers of E346K-NST, and they may well choose to emphasize different aspects of the texts discussed here. Other ways of organizing and teaching the course will also emerge. This tentative syllabus is meant only as a means of initiating discussion about the new course. As the course is offered to more and more students, feedback from the various teachers involved will enable us to test a variety of approaches and generate more proven syllabi. Responses and criticism of this first syllabus will be gratefully received.