HISTORY OF SCIENCE AS A DEVICE FOR RECONCILING THE SCIENCES AND THE HUMANITIES

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In the sixteenth century all knowledge was one. Whether one spoke of natural philosophy or of poetry or of history, it was universally held that such disparate fields blended together. The aim of Renaissance Humanism and of the Italian and French academic movements was to teach the encyclopedia (in the original Greek meaning of that term). In the seventeenth century the encyclopedic academies dissolved into specialized academies, at once both less esoterically ambitious and better adapted to the exponential increase of scientific and critical knowledge.[1]

The sixteenth century encyclopedic academies were susceptible to all the failings of any generalist movement. At their best, they tended to minimize important differences between competing schools of thought in their search for a syncretic philosophy. For example, it was overly optimistic to think that Plato and Aristotle could be forced into the same philosophic mold; it was chimerical to think that ancient Greek philosophers could be completely harmonized with Christianity. At their worst, such academies tended, by trying to explain too much, to explain nothing.

In a very real sense, then, the emergence of separate academies of fine arts, music, literature and science--the remains of which can still be seen in France's Académie des Beaux-Arts, Académie de Musique (now the Opéra) and in the various divisions of the Institut de France--was a constructive liberation of those disciplines from their previous bondage. Knowledge since the seventeenth century has increased too much to suppose that any one man could master it all. More recently, however, the compartmentalization of knowledge, necessary as it may be, has given rise to its own perils and penalties. Among the perils is the progressive narrowing of individual expertise; among the penalties is the increasing inability of even well-educated specialists to engage in meaningful discourse with one another. Out of this process has arisen the so-called "two-cultures" gap.

It has been fashionable in recent times to excoriate this gap. Ironically, it has been equally fashionable to congratulate oneself for standing on one side of the gap--whichever side that may be. Sometimes it has even served ideological interests to magnify its extent. Such fashions and ideological considerations may serve our own individual and collective psyches harmlessly enough. But there is a real danger that threatens education, in that we cultivate this sense of the "two-cultures" gap in our students. They thus grow up "realizing" that humanists are somehow different from scientists; that historians are unlike physicists. They dutifully discover themselves to be totally incompetent in mathematics or uninterested in literature, as the case may be.

We list only the most obvious "perceived" differences: the scientist's work is cut and dried; he has an infallible methodology which inevitably leads to scientific truth, which is absolute or nearly so; he has, withal, a humorless, robotlike mind which lacks any of the "oceanic" feeling to which humanists are prone; he is a moral cripple or worse; he is, consequently, a tool of governments, either unconcerned about the ramifications of his discoveries or in passive agreement with whatever technologically-oriented evil governments will do with them; he is a destroyer of mankind and an enemy of God.[2] Or, in a more flattering mode, the scientist is "perceived" as a high priest of an intellectual cult whose mysterious mathematical rituals shower mankind with material benefits. The humanist, on the other hand, is an inexhaustible source of words; he lacks a reliable methodology; he tends to

get lost in muddy global sensibilities; he never reaches a reliable or durable conclusion. Nevertheless, he possesses a certain warmth which exalts him to the level of true humanity.

In other words, an unbridgeable gap supposedly separates scientists and humanists, physicists and historians. Happily, this gap is largely illusory and far from unbridgeable. However, it does present two challenges to the instructor at the college level. The first is to provide a balanced education in the humanities and in the sciences to those many students who have already come to perceive themselves as lying irrevocably on one side of the gap or the other. The second, more subtle challenge is to demonstrate that it is the very belief in the gap that conjures it into being.

The first challenge is commonly met by administrative fiats for distribution requirements, though more diligent approaches are not uncommon and are often of admirable quality. Such approaches are typified by courses in the "physics for poets" genre and by analogous efforts on the humanities side. Whatever the quality of these efforts, however, they tend to aggravate the second part of the problem by segregating students. Few physics majors will be found in "physics for poets" classes and, conversely, few humanities majors will attend "poetry for technologists" classes. The very existence of such courses serves to confirm the student's belief that he requires a special (and presumably watered-down) approach to the "other" discipline. The type of educational integration needed to exorcise the "two-cultures" gap cannot be achieved by separate and not equal approaches.

In this article, we discuss two courses which aim at a unified approach to the humanities and the sciences. The first course is given at the senior level[3] and the second at the freshman level. They are the first of a projected cluster of such courses at all college levels. These courses do not seek to reintegrate the sciences and the humanities on a sixteenth-century basis, but to reopen discourse and understanding between them.

For catalogue purposes, the senior-level course is entitled "History of Science" and is cross-listed in the History and Physics-Astronomy Departments. However, the purpose of the course is not to teach the history of science as a specialty, nor is it to train professional historians of science. Our intention is to use history and physics as examples of humanistic and scientific disciplines as we inquire into their aims and methodologies both separately and in combination. Thus, the course is exactly as much a course in history as it is one in physics. This is the most unusual aspect of the course. By regarding the history of physics as a branch of intellectual history, we trace the constant interweaving and interaction of physical thought with other modes of thought through the historical periods under study. The syllabus does not particularly stress the impact of technology on society, but focuses mainly on the deeper interplay of contemporary currents of thought. It is mainly in the sense of this symmetrical approach that the course can make an honest attempt at bridging the "two-cultures" gap.

The course subtitle, "Toward a Metaphorical Theory of Science," stresses the essentially metaphorical nature of the modern scientific model. The idea of a model is traced from its simplest descriptive and mechanical origins (as in the Copernican theory and in classical kinetic theory) to its subtlest modern and abstract mathematical forms. Thus, the student is encouraged to see metaphor as the common property of all creative thinking. This insight comes as a surprise to almost all students, both "scientists" and "humanists." However, as will become clear in what follows, the specific theme of the course is not essential to the central philosophy of the approach. Indeed, we envision other courses based on other carefully chosen themes, to be taught concurrently by a scientist and a humanist.

The course has drawn roughly two-thirds of its students from the History and Physics departments; the remainder come from almost all parts of the University. By registering appropriately, the student may receive credit for a history elective, for a physics elective, or for a general education course in either physical or social science. We have been gratified to find that non-science majors do not enter the course seeking to use it as a dodge for fulfilling their science requirements with minimal exposure to science. We have similarly found that few if any physics majors regard the course as a "free ride" elective. This is in part due to the fact that the course is advertised as a "hard" one, requiring considerable reading and in-depth analysis in the form of essay responses to critical questions. These responses require a reasonable level of mastery of both historical and scientific ideas and materials.

We have felt from the outset that to teach the history of an intellectual modality (in this case, physics) which is itself not understood by many of the students, is to engage in pedagogical fraud of the worst sort. Consequently, a considerable amount of "straight" physics is integrated into the course. This introduction of real physics and its mathematical language at first frightens many non-science students. While mathematics through elementary algebra and rudimentary trigonometry (or the equivalent of about 2-1/2 years of high-school mathematics) is a prerequisite for the course, many students have largely lost whatever facility they may once have had in these matters. Care and tact are needed in introducing mathematical methods. Nevertheless, we have considered that it is unsound to dodge quantitative reasoning, since it is an essential component of the manner in which physical scientists think and express themselves. Fortunately, most of the mathematical techniques necessary to deal with the great physical ideas--at least up to the late nineteenth century--were invented with specific physical problems in mind. The requisite mathematics can thus be introduced in a "natural" way.

On the other side of the coin, we feared initially that the elementary introduction to physics for the non-scientists would waste the time of the physicists and bore them as well. Such has not been the case. The reason, we believe, is that the average undergraduate physics major approaches and thinks of physics as that set of techniques useful for solving physics problems. He seldom has the opportunity to stand back and realize that he has acquired a frame of reference and an overall method of approach which arise from the interaction of his mind with microcosms of particular problems and special techniques, and with the macrocosms of philosophical and historical developments. While there is no substitute for long experience and practice, we find that the historico-philosophical approach of our course hastens the happy day (all too frequently deferred at least to the graduate years) when the student becomes self-consciously aware of his understanding of the scientific enterprise, and of the power of that understanding both in itself and in relation to larger social and historical considerations.

Just as many "humanists" enter this course with some preconceived and unnecessary fears of a field whose language is mathematical, so, too, many "scientists" enter the course with a dread of history. They think history is compounded of rote memorization of major "facts" and dates as well as of somewhat boring causal questions (for example, "What were the causes and effects of . . .?"). They soon learn, however, that history is more complex and exciting than memorization and cut-and-dried interpretational slogans. Perhaps most important for the rehabilitation of the reputation of history, these students learn that to be a <u>good</u> historian is as difficult, and requires as much expertise and intuitive sense, as to be a <u>good</u> scientist.

In sum, both the non-science and science majors are drawn into the profounder issues of science and its development, the former by carefully laid

groundwork and the latter by new and striking insights into their daily studies. Both groups of students are able to demonstrate a substantial deepening of their understanding of physics as well as of the intellectual-historical process of its development. Both groups gain a deeper awareness of the philosophical implications of classical and modern physics. In sum, both groups of students profit substantially from both the scientific and historical elements of the course.

The freshman-level course, "Scientific and Humanistic Thought," is likewise cross-listed in History and Physics, and is taught by a scientist and a humanist. So far, enrollment in the course has been limited to students of demonstrated ability, though this restriction may be lifted in the future. Nevertheless, it goes without saying that one aims at greater breadth and less depth than in the senior-level course; the breadth is made manifest in the course title. We have found that a biographical approach engages the attention of the students, and makes possible an early introduction to the notion of style, especially in the sciences where most students are not prepared to expect that style is a meaningful idea.

As in the senior course, the mode of presentation is mainly one of informal lectures given by one or the other of the instructors, with much interpolated discussion. Both instructors are always present, and each feels free to interrupt the other (within reason) in order to add, to criticize, to present an alternative point of view, or to stimulate student discussion. We believe it to be very important in such interdisciplinary courses for students to see the instructors engaged in amicable criticism and to observe how the insights from an expert in one discipline can bear fruit in the thinking of an expert in another.

The details of the way in which the course operates depend crucially on the particular nature of the interaction between instructors. Consequently, we refrain from too much explicitness on this point. We doubt that such courses would be successful if two instructors were assigned at random. In any case, it is essential that they work out a compatible approach in advance, and that they be willing to modify it as necessary. Our experience has been that a good interaction between the instructors leads to an extraordinary degree of intellectual stimulation for them as well as for the students.

From the students' point of view, perhaps the most intriguing question that emerges is that of methodology. Having examined the personal and professional styles of Newton, Lavoisier, Einstein, and Watson, for example, we ask the question: Is there a scientific method? Students find the answer more complex than textbooks have made it out to be. The same question is asked concerning history, our prototype for the humanities. Here the traditional answer is clearer. History is known to have competing divisions: Marxist, structuralist, economic, social, intellectual, psychoanalytic, political, and so on. This plethora of methodological approaches, apparently conflicting and contradictory at least in some degree, has tended to undermine the credibility of the historian's craft, as perceived by the student.[4]

Thus, it is important that the student recognize that history and physics actually share a variety of methodological approaches. A brief consideration of certain developments in modern physics exemplifies this point. Two of the developments with the strongest ramifications for wider philosophical and critical issues are (a) the unpicturability of the atom and (b) the Heisenberg uncertainty principle. These schemata do not, of course, throw into question the validity of the laws of physical science, but they do make us look anew at the relation of the physical model to physical reality. This point can be advanced to good effect in both of the courses we have described. Nature, the physicist argues, does not mislead or trick us. But nature is not, as the

Positivists once thought, something that can be described with naive directness. To put it another way, we have no reason to expect that the universe is so fashioned as to make its comprehension as amenable as possible to the thought processes of the human mind.[5] Most physical scientists today recognize the essentially metaphorical nature of physical descriptions. That is, they realize the important difference between the reality and the human language which describes it.

The historical discourse faces the same problem. The position of the Positivist historians of the nineteenth century notwithstanding, there is a difference between "The Past" and "History."[6] The Past cannot be completely recaptured. The Past is or was the fluid and infinitely faceted situation in which human beings lived. Men in the eleventh century did not recognize trends that were leading to what we call the twelfth-century Renaissance; men in the late sixteenth century did not realize that certain artistic and literary styles were developing into what we call the Baroque. On the other hand, we do not know the totality of their thoughts and actions. We cannot re-find the Past; we can only re-create it. This re-creation which gives structure to a Past that knew no structure--in which people simply lived and acted--sees that incompletely known Past through the lens of the Present. It is thus, at bottom, an art form rich in metaphor. Comparison between historical and scientific discourse reveals the artistic, reconstructive nature of both.

The physicist interacts with nature through experiment. The experimental situation deliberately narrows the scope of possible interactions, so as to elicit a reliable answer to a rather sharply drawn question whose very specificity makes it significant. Similarly, the historian (even aside from the fact that he is always forced to rely on perhaps prejudicial, perhaps incomplete documentary sources) can only know the Past--i.e., can only write history--after it has taken form through his individual, socially conditioned subjective perception of and interest in that Past. V.H. Galbraith has said, "History, I suppose, is the Past--so far as we know it."[7] This is a fairly accurate statement, though there should be added, "and in the manner that we can know it."[8] Modern science has known an analogous subjective development. For example, medical science was transformed in the eighteenth century by a new approach of the physician to the patient.[9] Relativity theory was inaugurated by Einstein's youthful imagining of what it would be like to fly alongside a beam of light at its own speed. Neither of these scientific changes occurred in a vacuum; they were part and parcel of social-intellectual changes, just as is the history of each generation and of each historian.

Thus are students introduced to some of the social and esthetic similarities between science and history, and others of the humanities. It is not our purpose here to press for this rather personal schematic point of view. Rather we stress that it is out of such consciously if incompletely formulated attitudes on the part of the instructors that a fruitful learning experience can grow. Since great emphasis is put on the esthetics of science, as well as on its methodologies and techniques, many majors in the humanities realize for the first time the artistry of science. This awareness transcends knowledge of the history and philosophy of science. While such knowledge is certainly desirable, the two-cultures gap cannot really be closed until students come to view the scientific enterprise as an art form. This latter realization has two corollaries. First, there is the felicitous dethronement of science as a separate and superior discipline which exists and operates apart from all other activities of the human mind. Such traditional isolation of science has served neither science nor students well. On the one hand, it has placed science in a dangerous position, vulnerable to attack, due to a lack of comprehension of its true goals, its historical background, and its present intellectual components; on the other hand, it has given humanities majors an inferiority complex (sometimes couched under the veil of its opposite) which inhibits intelligent conversation and true communication within and without academe.

The second corollary easily follows. Demystified, science becomes the object of appreciation as a humanistic--that is, perfectly human--activity. Our humanities students have been especially cognizant of this transformation in the way they view science. They have felt no compulsion to take these courses, and they have entered them as co-equals with the science majors. They have become less wary of science and more able to discuss intelligently its history and purpose. Most important is the fact that they come to realize that science is not some kind of metasystem, but that it is rather one of a number of modes of thought, inquiry, and analysis which command the respect of thoughtful people.

APPENDIX A

COURSE OUTLINE: HISTORY OF SCIENCE

It should be noted that the outlines presented here and in Appendix B contain too much material for coverage at reasonable depth in a one-semester course. We usually cover about three-quarters of the material outlined, with choices and modifications dependent on the desires of the instructors and the students. We will be happy to supply interested readers with lists of required and recommended readings.

I. The Birth of Modern Science

1. Scholasticism, humanism, hermetism, and modern science.
2. Key events in "nonscientific" technology: The development of gunpowder warfare and printing.
3. The medieval view of a scientific enterprise: Medieval medical, physiological, and psychological views of women.
4. Operating on nature as a respectable intellectual activity: Magic and experimentation.
5. Giordano Bruno: Was he a scientist? His philosophical contributions to the scientific revolution.
6. Galileo: Scientific and philosophical contributions to the scientific revolution. Astronomical observations and falling bodies. The fate of Galileo as a resurrected Bruno.
7. Newton: Universal gravitation, Kepler's laws, classical mechanics. The evolution of mechanistic philosophies.
8. Impact of the new scientific thought on other branches of knowledge: Theological and philosophical thought. Toland versus the Newtonians; Hobbes and Locke; Descartes and Cartesianism.

II. Science in the Enlightenment

1. Scientific theories and extra-scientific models: "Scientific" economics and politics; "social physics."
2. The partially "self-conscious" production of theories. Lavoisier's chemistry and the Encyclopedists.
3. Overextension of faith in the scientific method and its entrenchment in popular thought. Unlimited optimism. Fontenelle, Voltaire, and d'Holbach.
4. The fate of science at the hands of liberal ideology and social revolution: The French Revolution.

III. Science from 1800 to 1900

1. Impacts of technology on science.
2. The triumph of kinetic theory and the mechanical model.
3. The "war" between science and religion.
4. The role of the scientist as discoverer of the exact form of nature.
5. The mathematical model as a parallel to and as a substitute for the mechanical model. The evolution of electromagnetism through Maxwell's equations and the rise to preeminence of the mathematical model.

6. Beginnings of the conscious and systematic application of science to technology. The rise of the engineering school.
7. Misuse of the "scientific method:" The sad case of social Darwinism.

IV. Science since 1900
1. Seeds of the quantum revolution: Atomic theories of chemistry; the faraday; e/m and e; Planck's law; x-rays and radioactivity; the photoelectric effect; Rutherford scattering.
2. The Bohr atom and the path to the new quantum mechanics.
3. De Broglie's hypothesis and complete wave-particle duality.
4. The failure of science as a path to absolute truth, and the tacit acceptance of science as a producer of metaphors.
5. The not-always-tranquil marriage of science and technology: Why do most people fail to distinguish the partners?

V. Science as the Creature of Its Time
1. Scientific method. Operationalism, Pragmatism, and Positivism.
2. What do people expect of science? What kinds of questions do scientists ask? What kinds of answers satisfy them?
3. Scientific style and/or its effects: How deeply does science affect other kinds of thought? Is there a period style in science? Is there an individual style in science?

VI. Speculations about the Future
1. Has the current metaphoric style of science penetrated other modes of thought? What impact may we expect?
2. Will the style of science change again? The Einstein-Bohr controversy revisited.
3. Has our preoccupation with the direct technological impact of science blinded us to more important long-range effects?
4. Anti-determinism, anti-intellectualism, cultural rejection, astrology, etc., as manifestations of counterexamples to a model of the long-range impact of science.

APPENDIX B

COURSE OUTLINE: SCIENTIFIC AND HUMANISTIC THOUGHT

I. Albert Schweitzer: A Humanist in a Scientific Age
1. Early life.
2. "Scientific" textual criticism and theology.
3. Analytical musicology, organ restoration, and musicianship.
4. Commitment as a medical missionary: Humanistic and scientific bases.
5. Schweitzer's doctoral dissertation. The general acceptance of Freudian psychoanalysis as a scientific theory. The implications of its application as such to the life of Jesus.
6. The medical missionary as scientist and humanist.
7. Reverence for life: Its humanistic and scientific sources and implications.
8. Modern interpretations of Schweitzer's life.

II. Albert Einstein
1. Early life.
2. Physics after Maxwell and Hertz.
3. The ether and the Michelson-Morley experiment.
4. The special theory of relativity.
5. The general theory of relativity.
6. Einstein as a popular hero.
7. Einstein as pacifist, internationalist, "Zionist," and humanist.

8. The impact of relativity theory on nonscientific thought and on the popular mind.
9. Einstein and quantum theory.
10. Einstein and the Nazis; antirelativistic ideologies; Lenard and others.
11. Possible impacts of modern physics (1905-1930) on the general thought of the coming century; analogies with the seventeenth century popularizers of Newton.

III. The Methodology of History
1. The historian and the climate of opinion.
2. The evolution of historical theory.
3. Competing schools of thought; e.g., the New Deal seen through the eyes of historians.
4. Is there a "scientific" history?
5. Present-day attempts to "dehumanize" history; e.g., Lévi-Strauss and Foucault.

IV. The Interrelations among Science, Technology, and Humanistic Thought
1. The manned space program.
2. The atomic bomb.
3. The Oppenheimer affair and McCarthyism.
4. Moral implications of science; scientific implications of morality.

V. Science as a Social Activity
1. J.D. Watson and the race for DNA.
2. Heroes and villains; winner and losers. Watson et al. vs. Rosalind Franklin; is science sexist?
3. Who pays? Who benefits? How?

NOTES

[1]Cf. F.A. Yates, The French Academies of the Sixteenth Century (London, 1947).

[2]This view has been set forth in vivid colors by such diverse commentators as Lewis Mumford, Theodore Roszak, and Alvin Toffler.

[3]The senior-level course is described in detail, together with some experiments at the high-school level, in L.S. Lerner and E.A. Gosselin, "History of Science As a Bridge Across the 'Two-Cultures' Gap," American Journal of Physics, XLIII (Jan. 1975), 13-19.

[4]We do bring to the students' attention here the Kuhnian view of the distinction between the two enterprises: that historical thought tends to proceed in more or less distinct schools, while scientific thought in any particular field is dominated, at any particular time, by a paradigm almost universally accepted. See T.S. Kuhn, The Structure of Scientific Revolutions, second edition, (Chicago, 1970). We do not stress the Kuhnian view, however. There is a current tendency to accept it uncritically, and to cover the question with reasonable thoroughness would take us too far afield from the central subject matter of the course.

[5]Einstein went still further and called the comprehensibility of nature a miracle. See A. Einstein, "Physics and Reality," in Out of My Later Years (New York, 1950), 59-65.

[6]See the discussion by H.I. Marrou, De la connaissance historique, seventh edition (Paris, 1975), 34-35, 49. The Positivists adopted the view that history was composed of the Past contaminated by an unavoidable addition of the

Present by the historian; the latter could, however, be reduced to a negligible level by proper diligence. More modern historians tend to the view that the Present is lens rather than contaminant, and is thus unavoidably and intrinsically present.

[7] Why We Study History, [British] Historical Association Publications, no. 131 (1944).

[8] With this difference: While it has been said that history has to be rewritten by every generation, the rewriting (i.e., the readjustment) of scientific discourse occurs less often. While the new is no less radical, it does less violence to the validity (though not to the philosophical underpinnings) of the old; however, it circumscribes the latter's sphere more explicitly.

[9] Cf. Michel Foucault, Naissance de la clinique, third edition (Paris, 1975), xiv.