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"The Two Cultures" and the Historical Perspective on Science as a Culture

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Abstract

In the Rede lecture of 1959, C.P.Snow speaks in terms of two cultures, one of science, the other of literary intellectuals. Snow's discussion presupposes that science represents a culture of its own, independent of and superior to the arts and humanities, and unified within itself. At our present distance from this claim, Snow's point of view can be seen as a product of the philosophical orientation to science as an embodiment of universal truths about nature as well as cold war pressures on the West to improve educational standards in science. As the terms in which science is discussed have changed in the last nearly half-century, so has our response to the terms of Snow's "Two Cultures"altered with time. The fields of history and sociology of science have shown the degree to which science is both fully enmeshed in society and conditioned by history, making it more difficult to support the idea of a separate "culture" of science immune from the effects of society and history. That the viability of a culture of science as an independent entity is contested in contemporary academic circles furthermore affects the mode in which students of science and the humanities are inculcated. This paper discusses the historical perspective on science as a culture and considers the impact of changing views about the nature, aims, and methods of science on the teaching of science and its history.

Introduction

The schismatic relation defined in the 1959 Rede lecture of C.P.Snow between the so-called cultures of science and of "literary intellectuals" presupposed the idea that science represents a culture of its own, independent of the arts and humanities and unified within itself. Snow pitted the two communities of intellectuals against one another as though they were foreigners looking suspiciously at one another over the border fence. Of course Snow referred only to modern science, though it will be my aim to open the question of the culture of science to a historical perspective. Implied in Snow's lecture, as well as by those who still invoke the two cultures, is an image and status of science as authoritative and universal, evidenced by its worldwide spread and currency.

In the mid-twentieth century, when Snow's Rede lecture was given, philosophers of science were concerned principally with the analysis of the nature of science as knowledge and the character of that knowledge from an epistemological point of view. It was by and large a point of

view that favored logical-empiricism with its strict criteria for meaning. The history of science was not considered to be terribly important to that mission. Scientific theories, at least those that were regarded as having certainty and demonstrability, were treated as though they had achieved a status of immunity from history. In his lecture, and especially in the follow up "A Second Look," Snow's view of science (especially applied science) as a veritable panacea for the suffering of the world was a kind of proof that science transcended history, and with it the failures of particular societies or individuals. Science, by means of its culture, had the capacity to elevate humanity by virtue of its collective, even universal, validity and power.[1]

By contrast with science's objective truths and transcendent achievements, Snow associated disciplines in the humanities such as literary criticism or other highly interpretative fields with a subjective form of thought and a consequent opacity to science. Such implicit enmity between scientists and humanists reflects an ideology built of what Barbara Herrnstein Smith calls "crude binaries." In her recent book, Scandalous Knowledge: Science, Truth and the Human (2005), she does, however, remark that the divide "may be, in some respects, even sharper and more extensive now than then [nearly 50 years ago], and the institutional, especially educational, mechanisms of their perpetuation even more deeply entrenched."[2]

This paper takes a critical look at the dichotomy of "The Two Cultures" from a historical point

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1.In this Snow was anticipated by 30 years in Neurath's desire to unify science for the good of mankind, in his "Wissenschaftliche Weltauffassung: Der Wiener Kreis," see Otto Neurath, Gesammelte philosophische und methodologische Schriften,I, ed. Rudolf Haller and Heiner Rutte (Vienna, 1981), 299-336, apud Martin Puchner, "Doing Logic with a Hammer: Wittgenstein's *Tractatus* and the Polemics of Logical Positivism," Journal of the History of Ideas 66 (2005), p.287 note 7. See also Richard Creath, "The Unity of Science: Carnap, Neurath, and Beyond," in Peter Galison and David J. Stump eds., The Disunity of Science: Boundaries, Contexts, and Power (Stanford, California: Stanford University Press, 1996), pp.158-169.

2.Barbara Herrnstein Smith, Scandalous Knowledge: Science, Truth and the Human (Durham, NC: Duke University Press, 2005), p.115.

of view. Scientific inquiry and knowledge manifest in various ways through history and across cultures, but despite the relationships such practices or bodies of knowledge may have to other socio-cultural realms, such as religion, metaphysics, or politics, certain unities enable us to refer to science, identify and describe the contexts within which such inquiry is practiced and knowledge is acquired. Non-empirical reasons for change in science can be a reflection of such varying integrations of science with other parts of human culture, and scientific theory can become the impetus for wholesale shifts in non-scientific aspects of a world-view, the Copernican Revolution being one of the very best examples of such change.[3] Science (as art, literature, history, or any other human endeavor) cannot be removed from its context. The historical perspective furthermore undermines the crude binaries of "The Two Cultures" by embedding science in the various social and intellectual contexts within which we find evidence of it, revealing ways that science influences and is influenced by other domains of thought.

The evident fact that not only science itself, but our view of what science is, changes with history invariably has an impact on how the sciences are taught, or should be taught, though such changes are not clear and distinct. The problem of "The Two Cultures" in science education, if a recent issue of the International Journal of Science and Mathematics Education is any indication, is very real. In the paper "Learning Science through a Historical Approach: Does it Affect the Attitudes of Non-Science-Oriented Students Towards Science?" authors Mamlok-Naaman, Ben-Zvi, Hofstein, Menis and Erduran framed their discussion with the following: "A wide gap currently exists between two communities, or rather two cultures–the scientists and the literary

3.Thomas S. Kuhn, The Copernican Revolution: Planetary Astronomy in the Development of Western Thought (Cambridge, MA and London: Harvard University Press,1957), R.S. Westman, "Two Cultures or One? A Second Look at Kuhn's *The Copernican Revolution*," Isis 85 (1994), pp.79-115, and N. M. Swerdlow, "An Essay on Thomas

intellectuals, a gap that seems to have widened considerably since 1955 [sic], when Snow first coined the term. The need for ever finer grades of specialization in the sciences has resulted in a situation where even scientists from different research areas find it difficult to communicate with each other."[4] The communication problem from scientists to non-scientists, or indeed between scientists in different specialized fields, is an inevitable consequence of rigorous specialization and training, but does not necessarily signal a break in thought, belief, and world-view such as would characterize two "cultures." The language barrier, in my view, is a separate issue from that of an alleged "culture" of science identified epistemologically and seen as fundamentally at odds with another alleged culture in the humanistic domain. This problem is directly related to one faced in the history of science, that is, just what disciplines belong within the classification of science and therefore what bodies of knowledge about physical phenomena belong to its history, and culture?

These three problems-- Snow's scientists and humanists, how to treat sciences in history, such as astrology, and the current debate over the teaching of modern Western science to the exclusion of other systems of natural knowledge--all represent manifestations of the problem of the demarcation between science and the non-sciences. The issue of the culture of science is tied directly to this more basic question.

The Culture of Science from a Historical Perspective

That scientific traditions have survived beyond the social contexts within which they are first

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Kuhn's First Scientific Revolution, *The Copernican Revolution*," PAPS 148 (2004), pp.64-120.
4.Rachel Mamlok-Naaman, Ruth Ben-Zvi, Avi Hofstein, Joseph Menis, Sibel Erduran, "Learning Science through a Historical Approach: Does it Affect the Attitudes of Non-Science-Oriented Students Towards Science?"

formed to be transmitted across cultures as diverse as ancient Greece and India (as in the case of mathematical astronomy) or ancient Mesopotamia and the Medieval West (as in the case of astrology), may give the impression that science is not bound to local contexts but has the ability to transcend both culture and history. But even such long lived scientific traditions as Western astronomy and astrology invariably experience adaptation through reception, adaptation which is itself determined by local social and conceptual differences. The transmission of science does not, after all, necessarily refute the historicist-constructivist view of science, which sees science not as involved in a process of discovery of the truths of nature, but rather as an engagement of specific historical communities of inquirers with the physical world. Such major transitions (revolutions) in scientific theory as from Babylonian to Ptolemaic astronomy, Ptolemaic to Copernican astronomy, or Newtonian physics to special relativity are seen by constructivists in the historicist mode as examples of the historically conditioned as well as socially and intellectually constructed nature of scientific theories or models of natural phenomena.

Since Near Eastern antiquity, science has functioned as the method for and body of knowledge about physical/natural phenomena in the world of our perceptions, experience, and imagination. The twentieth century, however, produced a philosophical tradition that shaped our thinking about science around a particular theory of meaning and truth known as verificationism, the hallmark of logical-positivism. By means of this philosophy, formulated in Vienna of the 1920's and 30's, science was demarcated from non-science on epistemological grounds. Scientific knowledge, being empirically verifiable, had no truck with the concerns of metaphysics, religion, or psychology, or anything without observational basis or consequence. Science stood in relation

only to nature, not to human culture. It was considered to be the single method of acquiring meaningful knowledge about the world.

The science of the post-war era, the science of Snow's time and to which he referred, is what we would dub "big science," epitomized by the high-energy physics labs requiring big budgets, big equipment, and a big laboratory workforce. The existence of big science was entirely dependent upon its social, political or industrial relevance, drawing for its sustenance on the national health budget, the defense budget, and money from big corporations.[5] Big science represented pure research, by its very nature untainted by local cultural prejudices, while its existence, at least the existence of the labs, think tanks, and huge government or privately funded projects, in fact depended upon a whole variety of social and political interests. Still, the "culture" of science in the rhetoric of "The Two Cultures" was privileged by its objectivity and truth, which gave it the authority and power to effect public good.

The widespread belief in the superiority of scientific knowledge in the post-war period, from 1946 until the early 1950's, saw a movement to bring science to bear on all matters of thought, including psychology, philosophy, and religion, as Peter Galison outlined in his "Americanization of Unity."[6] Despite the openness of this program to a rapprochement between science and the humanities, the conception of science among the founders and participants in the "Unity of Science" movement, such figures as Otto Neurath and Rudolf Carnap, was the one whose roots lay in the Vienna Circle with its positivism, rationality and objectivity. According to this

5. See Bruce Hevly, "Reflections on Big Science and Big History," in Peter Galison and Bruce Hevly eds., Big Science: The Growth of Large-Scale Research (Stanford: Stanford University Press, 1992), pp.355-363.
6.Peter Galison, "The Americanization of Unity," in P. Galison, S.R. Graubard, and E. Mendelsohn, eds., Science and Culture (New Brunswick and London: Transaction Publishers, 2001, originally published as Daedalus, Winter 1998 "Science in Culture"), pp.45-72.

conception, science was a phenomenon that resisted interference or influence from social factors such as world view, class, or politics.

The unity of science and its culture, culture meaning an Arnoldian set of high ideals that transcend a given society,[7] resonates with the rhetoric of Snow in "The Two Cultures,"and indeed forms the background for it. Snow called "the scientific edifice of the physical world... in its intellectual depth, complexity and articulation, the most beautiful and wonderful collective work of the mind of man."[8] He followed this declaration with the charge that non-scientists not only "have no conception of that edifice at all" but that "even if they want to have it, they can't."[9] It follows from such a view of culture and the unity of science that science and the humanities *would* constitute discrete worlds of meaning and distinct spheres of thought and activity and further, that science would always carry the bulk of the weight of intellectual capital. For this reason, nearly 50 years on from Snow's lecture, Hernnstein Smith notes "the evidently general assumption that, when a humanist (say, a professor of classics) fails to understand some scientific matter (say, the Second Law of Thermodynamics, as in Snow's notorious example), then it must be the humanist's fault (deplorable ignorance, indifference, ineptness and so forth), but when a scientist fails to understand the work of a humanist (say, the writings of some French philosopher), then it must *also* be the humanist's fault (deliberate obfuscation, intellectual fraudulence and so forth)."[10]

The superiority of the culture of science is reflected most explicitly in Snow's idea that science

7.Matthew Arnold, Culture and Anarchy and Other Writings, in Stefan Collini ed., (New York, NY and London: Cambridge University Press, 1993).
8.Two Cultures, p.14.
9.Ibid.
10.Barbara Herrnstein Smith, Scandalous Knowledge, p.121.

could provide hope and solutions to problems in human society. As well, Snow's position represents, as J. Golinski put it, "a kind of secular displacement of religious aspirations"[11] by viewing science as functioning in a soteriological way, saving and raising human beings out of the basest levels of subsistence and want. From this point of view, in which science provides a form of knowledge that saves humanity from itself, one should be surprised at the fact that science has not solved the problems of human suffering. We have certainly made good use of science for the improvement of human life, the global eradication of small pox and the synthesis of penicillin being two great success stories of modern science. However, no one observing the world would judge the lot of much of humankind to be free of suffering, despite achievements in many sciences and technologies. This, one might counter, is more the fault of the world's economy and politics than it is of science. That Snow's wish that science save the world never had the chance to come to fruition only underscores the degree to which science is not isolated from the world within which it is produced, but exists within a web of priorities and dispositions that have nothing to do with science per se.

Since circa 1960, the image of science as providing a unified foundation for the production of a form of truth about this world, a truth justified in the form of analytic statements (statements that are true by virtue of the meanings of their component elements) or empirically verifiable claims, has come under increasing scrutiny and scepticism. Some of the more recent responses

11.J. Golinski, Making Natural Knowledge (New York and London: Cambridge University Press, 1998), p.164. In Snow's words, "applied science has made it possible to remove unnecessary suffering from a billion individual human lives," see C.P. Snow, The Two Cultures: A Second Look (Cambridge: Cambridge University Press, 1969), p. 78. One cannot help but wonder how today Lord Snow might see science erasing the suffering in Iraq, Afghanistan and Darfur, Guantánamo and Bagram, those and other forms of suffering born of fanaticisms of one or another contemporary stripe (See Wole Soyinka, "I am Right: You are Dead," in Climate of Fear: The Quest for Dignity in a Dehumanized World [NY: Random House, 2004,2005], pp.115-142), or how he would respond to the very dilemma created by the fact that sometimes the purveyors of science and the purveyors of suffering are one and the same.

take the form of arguments for the disunity, social construction and contextualism of science. Prior to these more recent expressions of anti-foundationalism were objections to the idea of objectivity in the form of the theory-ladenness of observation,[12] or to put it another way, the false premise of a dichotomy between the "mental" and the "physical,"[13] the challenge to the reductive hypothesis and the notion of the sense datum,[14] and to the idea of the correspondence between scientific theory and the phenomenal world in the form of the underdetermination of theory by data.[15] The question of whether science "in general" can be characterized by certain kinds of knowledge, methods, or practices that serve to distinguish it from other intellectual pursuits has never been answered to everyone's satisfaction. More and more, philosophers with historians of science recognize the permeable boundaries between science and non-empirical systems of belief alongside of which science exists.

The 1960's were a fertile and volatile time in both the history and philosophy of science. Within a few years of the Rede lecture, the history of science began to have a serious impact on the philosophy of science, particularly in the American academy. A series of works appeared in the early sixties, the most important and widely disseminated of which was Thomas Kuhn's The Structure of Scientific Revolutions. Kuhn's thesis about change in the history of science was already prefigured in his The Copernican Revolution of 1957, but there the social dimension of science was not as central as it came to be in Structure. In a panel discussion given at LaSalle

12.N.R. Hanson, Patterns of Discovery (Cambridge: Cambridge University Press, 1958), p.19.
13.Gilbert Ryle comments on the fallacy of the mental and physical "status" of things in The Concept of Mind (New York: Barnes and Noble, 1949), pp.199-200, noting with clearly ironic undertones, "even the solemn phrase 'the physical world' is as philosophically pointless as would be the phrase 'the numismatic world', 'the haberdashery world', or 'the botanical world.'"
14.Ryle, The Concept of Mind, chapter 7 "Sensation and Observation," pp.199-244, and W.V.O. Quine, "Two Dogmas of Empiricism,"in W.V.O. Quine, From a Logical Point of View (Cambridge, MA and London: Harvard University Press, 1980, 3rd ed.), pp.20-46.

University in 1989, Kuhn indicated that as early as the 1940's he was already considering the social dimension of science.[16] He recollects his excitement at reading in the late 1940's the social science theories of Weber and Cassirer only to find these theorists disavowing the validity of their ideas when it came to science, which, in their view, was categorically different, or, as they said, "*ganz anders*."[17] What was "wholly other" about science was, in their view, that nature stood apart from human culture, was unaffected by our knowledge of it, and that the historical development of scientific knowledge represented a progressive accommodation of our thinking to nature itself. Kuhn's shift in perspective, exemplified by Structure not only made a social view of science more acceptable, but together with the historical turn came an interest in modifying the older (foundational, logical-empiricist) epistemology that was aimed at defining science and establishing clear cut boundaries around it particularly in defense of its truth-claims.

Modifications of the favored epistemology of science, however, were also already brewing within the philosophical community. Though the view of science as inviolable and impervious to the influences of human culture had become relatively entrenched as a result of the positivist program, this evokes too simple a depiction of the philosophical landscape of the twentieth century with respect to science. In the same year as the Rede lecture, for example, the English translation of Popper's 1935 The Logic of Scientific Discovery was published.. Popper's variation on verificationism still targeted the problem of demarcating science from non-science, but offers a far less dogmatic picture of the nature of scientific knowledge. In an appendix to

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15.W.V.O. Quine, "On Empirically Equivalent Systems of the World," Erkenntnis 9 (1975), pp.313-328.
16.Thomas S. Kuhn, The Road Since Structure: Philosophical Essay, 1970-1993, with an Autobiographical Essay , edited by James Conant and John Haugland (Chicago and London: The University of Chicago Press, 2000), pp. 216-223.
17. Ibid., p.216.

The Logic of Scientific Discovery, in a note on the logic of induction and a denial of the justification or verification of any scientific theories, he said, "I think that we shall have to get accustomed to the idea that we must not look upon science as a 'body of knowledge,' but rather as a system of hypotheses; that is to say, as a system of guesses or anticipations which in principle cannot be justified, but with which we work as long as they stand up to tests, and of which we are never justified in saying that we know that they are 'true' or 'more or less certain' or even 'probable'."[18] Popper put little stock in the sole empirical basis of "objective science," finding "nothing absolute about it."[19] Whether this position is anti-foundationalist is a matter for closer analysis of Popper than the present scope allows.

What is of interest for our appreciation of the historicity of Snow's point of view is that among the ranks of philosophers of science, the ground for maintaining an exclusively rational and empirical foundation for science was shaking, and with it a certain view of the nature of scientific knowledge and a scientific culture. While a system of hypotheses does not a culture make, one can perhaps see how a received "body of knowledge" of a particular epistemic character, especially one which is thought to confer certain (rational) habits of mind upon both the individual and her social/intellectual community, might be taken to constitute one. Indeed, to maintain the separateness of the "culture" of science, according to the "standard view,"[20] required

18.K.R. Popper, The Logic of Scientific Discovery (London and NewYork: Routledge, 2003, first published 1934, Springer Verlag, first English edition 1959, Hutchinson & Co.), p.318.

19.Ibid., pp.93-4. It is worth quoting the entire passage: "The empirical basis of objective science has thus nothing 'absolute' about it. Science does not rest upon solid bedrock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or 'given' base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being."

20.See I. Scheffler, Science and Subjectivity (New York: Bobbs-Merrill, 1967), especially pp.7-15, and M. Mulkay, Science and the Sociology of Knowledge (London: George Allen & Unwin, 1979), pp.19-21 and passim.

the special relation of science and its hypotheses, or "knowledge," to the rational at the expense of other forms of thought that do not demarcate science from other things. This points to the very problem of the notion of the culture of science as a set of practices, ideas, or knowledge cordoned off from other cultural "zones."

In the aftermath of Kuhn's Structure, the sociology of science and the sociology of scientific knowledge emerged in the 1970's, committed more strongly to the idea of knowledge as a product of the interaction between observer and experienced world, expressed in divergent languages of observation (and theory). This shift in the basis of scientific epistemology raised questions of the relation of scientific knowledge to the "reality" observed or experienced by the observer, and indeed, whether observers subscribing to different theories in fact "see" different phenomena in the same "world." N.R. Hanson famously questioned whether observers subscribing to different theories in fact "see" different phenomena in the same "world," his most apposite example being the question of whether Kepler, who regarded the sun as fixed and the earth as moving, and Tycho, who regarded the sun as moving and the earth as fixed, "see" the same thing in the east at dawn when the sun rises.[21]

The question of the relation of knowledge to reality was ultimately answered by some sociologists of science with the words, "as we come to recognize the conventional and artifactual status of our forms of knowing, we put ourselves in a position to realize that it is ourselves and not reality that is responsible for what we know."[22] This has the feel of another crude binary (either there is a real world out there that we come to know, or everything we know is a complete

21.Norwood Russell Hanson, Patterns of Discovery (1965), p.5.
22.Steven Shapin and Simon Schaffer, Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life (Princeton: Princeton University Press, 1985), p.344.

"construction," a function of our mind and language[23]), and of course not everyone agreed with this answer. Scientific realists, for example were reluctant to part with a mind-independent "reality," insisting it is the very thing that makes scientific consensus possible. But the realists' position was countered on the basis that it presupposed the notion that objects of knowledge are given to us directly through our observations but unmediated by culture, language, or cognition.

Knowledge unmediated by culture, language, cognition, or history, or more precisely, the question of whether knowledge can be justified without appeal to experience or the empirical, remains a vexed question for contemporary epistemologists. The sociology of science and its brother in the UK, the sociology of scientific knowledge, or Strong Programme, focused on the place of science and scientific knowledge in context, whether macro (e.g., American society) or micro (e.g., the laboratory) and they shared a commitment to the idea that not only is science socially and historically situated, but criteria that demarcate science from non-science are similarly situated. The implications of the sociology of scientific knowledge for the history of science were profound because it called into question the rigid demarcation criteria that had been used by logical-empiricists, or rather historians influenced by a logical-empiricist notion of science, to determine what counted as historical evidence for science.

To arbitrarily impose such criteria upon all manifestations of science in history was finally recognized as anachronistic, the result of which was then pejoratively designated "Whig" history of science. The consequence of the relationship between the historian and her reconstruction of science in the past, whether fifty, five hundred, or 2500 years ago, is that she finds herself caught within a tension between, on the one hand, the fact that all historical reconstructions unwittingly

23.Here we return to the fallacy described by Ryle in his discussion of the false antithesis between inner and outer,

reproduce anachronistic concerns of the present, and on the other, the need precisely not to do merely that. The integration of science into its historical, social, and intellectual contexts is productive not only in combating Whiggism, but in actually contributing, through the evidence of history, to a fuller understanding of the nature of science itself.

The perspective on science as a fully social phenomenon has gained ground since its inception in the 1960's and now flourishes in the sociology of science, "cultural studies of science," or "science studies." The practice of science has assumed greater significance in science studies over epistemology. This approach to science as a social and cultural phenomenon does not accept the view that science maintains a separateness in virtue of a particular identifying epistemology. Accordingly, the unity of science has been challenged. As J. Dupré noted, "on the one hand, to historians and sociologists looking in increasing detail at the fine grain of scientific practice, the contingency and specificity of particular projects of inquiry have made the idea of science as one grand project incredible. And on the other hand, epistemologists concerned with the claims to knowledge of particular branches of science have not easily fitted these local modes of justification into broad patterns with universal applicability."[24]

A different sort of challenge to universality was made by Kuhn in the 1989 panel on "the Natural and the Human Sciences," already referred to before.[25] There he outlined the way in which he was inclined to draw the line, or not draw a line, between the human and the natural sciences. What he argued *against* there was the notion of the uniformity of nature, i.e., that

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mind and matter, private and public experience. See The Concept of Mind.

24.John Dupré, "Metaphysical Disorder and Scientific Disunity," in Peter Galison and David J. Stump, eds., The Disunity of Science: Boundaries, Contexts, and Power (Stanford, CA: Stanford University Press, 1996), p.101.

25. His remarks were published in The Interpretive Turn: Philosophy, Science, Culture, edited by David R. Hiley, James F. Bohman and Richard Shusterman (Ithaca: Cornell University Press, 1991).

cultural relativism can apply to human behavior but not natural phenomena. He did not see that natural phenomena were "the same for all cultures"[26] and remained unconvinced by the argument that because nature stands apart from human culture, existing independently from our actions and our knowing, that its phenomena are necessarily or categorically unaffected by culture. He suggested that not only are concepts ("of the natural or social world") "the possession of communities (cultures or subcultures)," but social concepts as well as concepts of the natural world "shape the world to which they are applied."[27] Kuhn said, for example, "the heavens of the Greeks were irreducibly different from ours ... that does not mean that one cannot, with sufficient patience and effort, discover the categories of another culture or of an earlier stage of one's own."[28]

It is worth looking a little closer at "the heavens of the Greeks" as a clear example of the historicity of scientific knowledge and theory as well as the permeability of science to non-empirical considerations. The conceptualization of the heavenly spheres is a case in point, as is the theory of the circular motion of the planets. The notion of the spherical heavens goes back to Plato's Timaeus (33B-34A) which argues that the creator of the world, the Demiurge, made the physical universe the most perfect of forms. This perfection of bodily form was defined as that which was the most uniform and could be in motion without changing place, i.e., ceaselessly rotating about itself. The shape of the world was said to be "a figure the most perfect and uniform of all." And this was desirable because "he [the Demiurge] judged uniformity to be

26.Kuhn, The Road Since Structure, p.218.
27.Ibid., p.219.
28.Ibid., p.220.

immeasurably better than its opposite."[29] This statement reveals a fundamental ethical dimension to Plato's cosmology. The theory of the spherical cosmos in Aristotle's treatises On the Heavens, the Physics, and Metaphysics develops the argument differently, but the idea of the sphere as the only suitable form for a body characterized by perfection and eternity is retained (e.g., On the Heavens, Book II.1). The circular motion of the heavenly bodies follows from the eternal spherical heavens, explained as follows: "Therefore we may well feel assured that those ancient beliefs are true, which belong especially to our own native tradition, and according to which there exists something immortal and divine, in the class of things in motion, but whose motion is such that there is no limit to it. Rather it is itself the limit of other motions, for it is a property of that which embraces to be a limit, and the circular motion in question, being complete, embraces the incomplete and finite motions."[30] In Aristotle's cosmos, the matter of which the heavenly regions consist is aether, the fifth element, which is eternal, incorruptible, and divine because its natural motion is circular (On the Heavens, Book I..3). Nearly 450 years later, Ptolemy established observational reasons for the sphericity of the heavens, both from the risings and settings and fixed distance of fixed stars with respect to earth, and from the fact that sundials work. (Almagest Book I.3, H 11 and H 13).[31] The uniform circular rotations of the planetary bodies follows from the Aristotelian cosmology that underpins astronomical models such as Apollonius', though such models do not account for observed irregularities in planetary motion (the retrograde arcs, for example) or in the inequality of the seasons (zodiacal anomaly). These were considerations taken up in the Almagest that led to Ptolemy's modifications of the epicyclic models of his

29.Plato, Timaeus, 33B, in Cornford, Plato's Cosmology (Indianapolis, IN: Bobbs-Merrill, 1975, 5th printing), p. 54.
30.Aristotle, On the Heavens, Book II..1 284a, transl. W.K.C. Guthrie (Cambridge, MA, Harvard University Press, Loeb Classical Library VI), pp.131-2.

predecessors, namely to the creation of the eccentric and equant models of the planets. But Ptolemy's modifications of astronomical hypotheses were nonetheless constrained by the Aristotelian finite spherical and uniformly moving heavenly regions, which were justified on metaphysical grounds.

For observers of the heavens, i.e., astronomers, astrologers, and cosmographers, of Western antiquity to the Renanissance, the "reality" of the heavens was, if nothing else, assumed to consist in the celestial spheres. The visible heavens were accordingly "seen" as the finite (generally speaking the eighth) sphere of the fixed stars with the planets at varying distances from earth, the point from which we make our observations at the center of the entire structure. It is well-known that subsequent to the Copernican revolution, the universe opened and the celestial spheres dissolved, giving way to speculations about an infinite universe. We no longer think of ourselves as making celestial observations from the center of the entire structure. Less well-known is the fact that prior to Greco-Roman antiquity, for well over a thousand years, the celestial observers in ancient Mesopotamia had no conception of celestial spheres or of an infinite universe.[32] Despite such different dispositions with respect to the world as a whole, all three cultural traditions, i.e., the ancient Near East, the Greco-Roman and the later West, i.e., European Mediaeval, Renaissance, and modern, produced astronomical sciences that not only reflect their own particular cosmological orientations but also serve predictive and theoretical goals which we, from the modern Western point of view identify as "science."

Examples could be multiplied from other scientific disciplines from antiquity to the modern

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31.G.J. Toomer, Ptolemy's Almagest (New York, Berlin, Heidelberg, Tokyo: Springer Verlag, 1984), pp.38-39.
32.F. Rochberg, "Mesopotamian Cosmology," in Daniel C. Snell, ed., A Companion to the Ancient Near East (Oxford: Blackwell Publishing, 2005), pp.316-29.

era. The point is, what we classify as physical (or natural) science in history has been positioned in a variety of relationships to what we classify today as non-science, i.e., magic, religion, metaphysics, as a result of the diverse ways human beings have responded to and sought to understand the natural world. The difficulty philosophers have faced in attempting not only clear cut demarcation criteria for science, but also to discern which is more determinate for the nature and content of science, the external (world) or the internal (mind), is concretized and underscored in the historical record.

Effects on Pedagogy

Changes in the way science is understood within the history and philosophy of science community of the last nearly twenty years, and in some ways reaching back even further, stand as an implicit or potential critical commentary on Snow's (not philosophically well-defined) take on science, particularly his salvational claim made for science in society. Still, Snow's idea was to facilitate a route by which all nations and peoples could benefit from industrialization and the "scientific revolution." That route was cultural via pedagogy, and he implied that a culture in which educators and administrators cannot bridge the intellectual gap between the sciences and the humanities, meaning of course to learn and excel in science, is doomed to failure.

I cannot nor do I wish to dispute the wisdom of maintaining educational standards in the sciences. Moreover, distressing hard evidence of declining performance in science achievement in American secondary schools, the latest statistics showing a drop in 12th grade science tests over

the past decade, should not be ignored.[33] Just why this steady downgrade in student performance in science is the case is a matter for discussion far beyond the range of the present paper and the competence of its writer. I will confine myself here to some comments on the role of the history of science in science education, at least what educators seem to have to say about this, and to raise the question what exactly it is about learning science that seems to be so important.

In addition, I would like to point out that the recent debate in the science education community concerning the relation between modern Western science and traditional non-Western forms of thought about nature also belongs under the rubric of "The Two Cultures" problem, viz., that between science and the non-sciences (be they humanities or so-called indigenous sciences). The current issue for educators focuses on the question of what form or body of knowledge about nature should be taught, or at least foregrounded. Those who advocate the teaching of modern Western science to the exclusion of all other forms of knowledge about nature argue their position on the basis of the universality of modern Western science, versus the local status of "indigenous" sciences. The problem of definition and classification is the same as that faced in the history of science, namely, what to include within the classification of science and whether a definition of science as a culturally transcendent, even universal, form of knowledge is justified.

A good many, and prominent, educators have rallied behind the cause of integrating the history of science into the general science curriculum.[34] Project 2061, an initiative of the American Association for the Advancement of Science,[35] solidly supports the inclusion of the history of science toward science literacy in the curriculum. The commitment to history of

33.Sam Dillon, NYTimes May 25, 2006.
34.See Michael R. Matthews, Science Teaching: The Role of History and Philosophy of Science (New York and London: Routledge, 1994), ch. 4 "History of Science in the Curriculum."

science in the curriculum has a solid patrimony, going back, for example, to James Bryant Conant's General Education in a Free Society: Report of the Harvard Committee of 1945. M. Matthews notes, however, that "unfortunately most countries allow students to complete history courses without any knowledge of major scientific, mathematical and technical achievements, which constitute some of the most important episodes in the development of civilization. If as much history time were devoted to the scientific revolution as to political revolutions, to Mendel and genetics as to generals, to the development of timekeeping as to the development of constitutions–then the overall education of society would be considerably advanced, and the 'two-cultures' gap lamented by C.P. Snow would be less apparent."[36]

The science education literature suggests the importance not only of history and philosophy of science but also social and political history to the teaching of science. Conant, scientist and president of Harvard University in the early 1930's, wrote in his essay "On Understanding Science: An Historical Approach" (1947) about the "interconnection between science and society" (p.32) and how this was more important for the non-science major than knowledge of scientific fields per se. He said, "the development of science [is] an organized social activity. [There is an] interconnection between science and the general culture of the times...a minimum of it is essential to understanding science, I believe..."[37] As R. Hendrick points out, Conant's idea was prefigured in 19th century France in a movement to popularize science so that France would be stronger, have more patriotic and capable citizens. Louis Figuier, a chemist and great

35.See www.project2061.org/.
36.Ibid., p.52.
37.James B. Conant, "On Understanding Science: An Historical Approach," apud Robert M. Hendrick, "The Role of History in Teaching Science–A Case Study of the Popularization of Science in Nineteenth Century France," Science & Education 1 (1992), p.147.

popularizer of science, according to Hendrick's account, recommended that the "lessons of science would inculcate virtue in his readers, especially in children." [38] Further, that this would avoid "the 'menace' of socialism," be good for France politically, and Figuier called science the "God of Battle."[39]

What precisely about learning science has such a salutary effect on the mind if exposure to science in a popular and simplified form is similarly efficacious? As one popular science writer and geographer Elisée Reclus said, referring to his popular writing, "what I am working at is hardly science."[40] This seems to demonstrate a fallacy in the thinking about "The Two Cultures," namely, that only by entering the "culture" of science is the human mind improved and with it society itself. In the case of France in the 19th century, it was education *about* science, not *in* science, that seemed to make the difference. Similarly, Hendrick's article argues that the way to reverse the deplorable level of knowledge and understanding of science in American schools is to disseminate, through popular science and even fiction (the science novel and science fiction), knowledge *about* science. He quotes 1988 Nobel physicist Leon Ledermann as saying "it is probably more important for the non-science major to acquire an understanding of how science works and how it interacts with other social forces, than it is to have that student memorize a large body of scientific facts. Unfortunately, these facts will usually be quickly forgotten, but the comprehension of how science works will be retained and will stand the student in good stead as a mature, voting adult."[41]

It appears that entry into a culture of science as part of a formal education is a privileged route

38.Ibid. p.150.
39.Ibid.
40.Quoted by Hendrick, ibid., p. 153.

among many (or several, at any rate) to rationality and critical thinking. Those who would blame the inadequacies of science education for not successfully imparting to our children the ability to reason perpetuate the unproductive notion of science as salvational. M. Matthews, in his Science Teaching: The Role of History and Philosophy of Science (1994), went so far as to claim that a lack of science education would allow superstition, ignorance and even fanaticism free rein in our culture. The idea is that if only teachers would impart a science education to our students, the young would not fall prey to the dangers of irrationality and an uncritical habit of mind. Matthews points out that "various researchers suggest that only forty-five percent of adult Americans know that the earth goes around the sun once each year. A third believe that boiling radioactive milk makes it safe to drink. Some forty percent believe that aliens from outer space have visited Earth, and fifty-four percent reject the idea that humans evolved from earlier species."[42] He rightly considers such numbers "culturally alarming" and symptomatic of "widespread antiscientific views, and illogical thought,"[43] but goes on to say that "when thought becomes so free from rational constraints, then outpourings of racism, prejudice, hysteria and fanaticism of all kinds can be expected."[44] There is no doubt that if we are educated in the sciences, we will be more rational citizens, but education in non-scientific disciplines, say literature or history, also certainly impart rational and critical thinking. But who is to say from which of these forms of training the mind becomes more rational and the citizen ultimately "better"? This was the unfortunate implication of C.P.Snow's "The Two Cultures," namely, that science refined the mind by rationality, method, and critical thinking, whereas the humanistic

41.Ibid., p.145-6.
42.Matthews, Science Teaching, p.30.
43.Ibid., p.5.

fields did not, or did to a lesser and inadequate degree.

It is no doubt the case that learning science is not like learning poetry, languages, or music (think harmony and counterpoint), but the differences cannot be measured in terms of a presence or absence of rationality or the need to exercise analytic and critical thinking with precision and rigor. Even more difficult to defend would be the claim that science produces and refines ethical judgment and thereby prevents racism, hysteria and fanaticism as a result of training in mathematical predictive methods, the structure of physical theory, or the practice of observation, experimentation, testing and falsification. The separation of science from other forms of learning, while legitimate from many points of view, has not been successfully drawn from a purely epistemological standpoint.[45] And it is the putative epistemological distinctiveness, characterized by its ability to generalize and predict, that is appealed to by those who claim a separate culture for science and a superior role for science in education.

Philosophical issues about the nature of science and the impact of the history of science on the discussion, particularly concerning the question of universality versus relativism, bear on another aspect of science pedagogy. In 2001, an entire issue of the journal Science Education was devoted to this topic, publishing the papers given at the 1998 annual meeting of the National Association for Research in Science Teaching.[46] While the participants agreed that all sciences reflect the cultural contexts within which they emerged (the notion of science as "culture-laden"), the question remained if modern science belongs to and transmits Western cultural thought,

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44.Ibid., p.5.
45.See L. Laudan, "The Demise of the Demarcation Problem," in R. Lauden ed., The Demarcation between Science and Pseudo-Science, vol.21 (Blacksburg, VA: Virginia Tech Center for the Study of Science in Society, Working Papers, 1983), pp.7-35.
46.See Science Education 85/1 (2001).

should it dominate science education across the board in a culturally diverse world. The terminology of "border-crossings" invoked in this particular debate about learning modern sciences, however, merely perpetuates the concept of "The Two Cultures," by retaining an essentially mid-twentieth century definition of science and viewing all other forms of knowledge about nature as outside its domain.[47] Because this definition has already been repudiated and the demarcation between science and non-science is no longer viewed as a cut and dried dichotomy, at least among philosophers and historians of science, the basis on which a demarcation is still drawn appears to be political. The worry about the potential of a science education to undermine cultural belief systems in non-Western countries does not stem from an inherent quality of modern Western science to affect the mind. Any Western system of thought of any kind, if introduced and absorbed through education in a non-Western context, would have a similar "disintegrating" effect, potentially. At stake therefore is not so much the epistemological or universal character of modern science, but the potential for science education to implement a politics of exclusion. The question of the validity of "The Two Cultures" in the context of education then rests on a deeper pedagogical question concerning the purpose of education, or the relative weights of its purposes, as an instrument of cognitive development or of social change.

Conclusion

It is a matter of some irony that Snow's conception of scientific knowledge as embodying universal natural truths is exactly parallel to his contemporary and arch adversary, the literary critic, F.R. Leavis' conception of literature, i.e., that literature embodied the highest expression of

47.G. Snively and J. Corsiglia, "Discovering Indigenous Science: Implications for Science Education," Science

universal human truths. Though the two men shared this desire to find in the cultural forms of literature and science expressions of universality and truth, and held to a hierarchical view of greatness in human achievement, Leavis, in his scathing diatribe, Two Cultures?,[48] pronounced Snow "portentously ignorant"[49] and assessed his lecture as exhibiting "an utter lack of intellectual distinction and an embarrassing vulgarity of style."[50] Leavis' critics, such as Raymond Williams, in 1961, leveled the same charge against him that some historians and sociologists of science would level against Snow, namely**,** that literature was not, as J. Brannigan put it, "a privileged form for the expression of genius, nor as a league table of achievements in subtlety and complexity of language, but rather as one form of social experience and practice."[51] Both Snow and Leavis subscribed to the same notion of culture as a great and canonical tradition to be received and transmitted as such, in contradistinction to their critics, e.g., Raymond Williams and subsequent other new historicists from the literary critical side, Kuhn and subsequent sociologists of science and post-positivist historians of science from the history and philosophy of science side, who all view culture as conditioned by history and as such reflective of the continually changing societies within which literature and science are produced.

Though the binaries are still both internalized and projected in certain contemporary contexts, the view that polarizes science and the humanities as "two cultures" seems to me as artificial and contrived as Herodotus' hard (Scythians and Greeks//scientific) and soft (Egyptians and

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Education 85 (2001), pp.6-34.
48.F.R. Leavis, Two Cultures? The Significance of C.P. Snow (Chatto and Windus,1962; Random House, 1963).
49.Ibid., p.28.
50.Ibid., p.30.
51.John Brannigan, New Historicism and Cultural Materialism (New York: St. Martin's Press,1998), p.38. For Raymond Williams' excursus on Leavis, see his Culture and Society 1780-1950 (Harmondsworth: Penguin, 1961), pp.252-63.

Persians//humanistic/literary) cultures, a parallelism to which Herrnstein Smith alludes in her book Scandalous Knowledge.[52] Herodotus differentiated between peoples precisely in a cultural sense (habits, dress, manners), but ultimately in a moral sense, to the detriment of the soft, who always lose in war.[53] Today there is a profound sense in which science plays a role in culture and society that is of the essence in matters of military competitiveness and national security. If we allow ourselves to slip in science education, we set the stage for slippage in military technologies and other such measures of national strength.[54] This is, sadly, the reality of the contemporary situation.

The history of science undercuts the claim that a rigid dichotomy exists between science and the humanities by showing the various observational and theoretical "styles"[55] of Western science over the course of its development. From a different angle, the postmodern critique of science education also seeks to undercut the same dichotomy. Not only does recent history indicate the ephemeral nature of the perspective defined in "The Two Cultures," but the history of science as a whole serves to demonstrate even more strongly that science, the arts, and humanities have assumed a variety of relationships to one another, and will continue to do so as each of these domains of thought and practice undergo metamorphoses, some of which as a result of their mutually permeable relationships.

52.For full citation, see note 2.

53. Cyrus reacts to the suggestion that the Persians abandon their barren country and take another, better one: "Soft countries," he said, "breed soft men. It is not the property of any one soil to produce fine fruits and good soldiers too." Herodotus, Histories, Bk.9:122.

54.Donald Kennedy, "Two Cultures," Science 299 (2003), p.1148, speaks of a new divide between the cultures of the national security community and the scientific community, the conflict between them centering on the question of the publication of sensitive data and research. Communication between these two cultures was addressed in a meeting sponsored by the National Academies and the Center for Security and International Studies.

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55.See G. Buchdahl, "Styles of Scientific Thinking," Science & Education 2 (1993), pp.149-68.

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