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## THE PHYSICAL SCIENCES AMONG THE LIBERAL ARTS

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This symposium celebrates the addition of wonderful resources for teaching the physical sciences to college students, resources that include new levels of commitment of time and energy by the faculty as well as these elegant facilities. I feel pleased and honored to have been called to participate in so felicitous an occasion.

My formal assignment was to respond to this occasion from the viewpoint of a humanist. That assignment, I must confess, made me a bit uncomfortable, for it could be taken to presume the notion of a fundamental opposition between "science" and "humanities." I am well aware that this opposition has been embedded in our thought patterns for many generations. The opposition is nevertheless objectionable.

It is objectionable, first of all, on strictly logical grounds, for, as you are well aware, it is difficult to conceive any criterion that can be held absolutely and without qualification to divide the work of natural scientists and that of humanistic scholars. For example, the old notion that science deals with universals and the humanities with historical particulars surely does not hold, since important parts of astronomy and geology are historical in character while many humanistic disciplines, like linguistics and philosophy, strive for universal generalizations. The notion that the sciences provide objective representations while the humanities are permeated by subjective bias does not hold, since modern physics has surely demonstrated that the situation of observers inexorably conditions what they will see, while throughout the humanistic disciplines powerful new measures and procedures to counteract bias have been devised. The notion that the humanities only describe while science predicts does not hold, since the sciences are powerless to predict the exact particulars of most future events occurring in nature, while the humanistic disciplines have been able, *grosso modo*, to predict coming developments in styles, language patterns, and thought ways. The notion that the sciences are quantitative while the humanities are not collapses before the enormous application of mathematical logic, statistics, and computerized calculation throughout the domain of human studies in the last generation, while important reaches of natural science, in particular biology, remain irreducibly non-quantitative in confronting some of their most important problems. The notion that the sciences employ a purely theoretical or cognitive perspective while the humanities adopt moral and aesthetic perspectives does not hold, since judgments about the relative worth of diverse scientific programs and styles of inquiry necessarily invoke moral and aesthetic criteria, while cognitive criteria are of course highly salient in the evaluation of humanistic

serendipitous stimuli provided by students asking apparently innocent questions. Just last quarter I heard from one colleague that he had been challenged and indeed stumped for three weeks by just such a question, and others have reported that entire new research programs had been the outcome of queries of that sort. Nobel Laureate James Cronin, of our Department of Physics, put the matter as follows:

When I have to explain to [undergraduates] what my current work is, I find myself having to think things through very clearly in order to explain it to them, and in the process I sometimes find myself thinking about the problems I am working on in new ways.

Finally, in order to participate fully in a well-conceived curriculum, an instructor must necessarily collaborate with other colleagues, often with those from neighboring disciplines. At Chicago we have found time and again that this type of collegial interaction has provided points of exchange and intellectual stimulation that have been highly beneficial for the scholarly work of our faculty.

To say such things to this audience, I surmise, is to talk to the converted, so let me return to my point of departure, the persisting sense of opposition between "the two cultures," and simply assert: *Any exclusion of the natural sciences from the domain of the liberal arts has to be regarded as historically parochial and intellectually indefensible.* To justify these two claims will be the burden of my remarks today. In concluding, I shall ask what these arguments imply about how best to teach physics and chemistry as integral components of a liberal education.

The core idea of liberal learning developed at about the same time in the classic cultures of ancient China and Greece. In Greece this kind of educational aspiration was linked to the ideal of *paideia*, the notion of using culture as a means to create a higher type of human being. According to Werner Jaeger, who wrote a celebrated book on the subject, the Greeks believed that education in this sense "embodied the purpose of all human effort. It was, they held, the ultimate justification for the existence of both the individual and the community" (1939: xvii). The kind of learning that elicited such enthusiasm stood in contrast to the training undertaken simply for the purposes of survival or mundane utility, a kind of training known as *banausic* or illiberal. Liberal learning, rather, was that held to befit a free person: learning that is undertaken for its own sake, learning that is appropriate for promoting happiness and a good life. The curriculum of that ennobling education consisted of work in a number of well-defined intellectual arts, as well as the arts of music and gymnastics. The intellectual arts, those pursuits whose cultivation best realized man's highest potentiality, included mathematics and physics (broadly understood as the science of natural things) along with ethics, politics, poetics, and rhetoric.

In ancient China, a cognate notion of education as the way to produce a broadly cultivated person appeared during the Chou dynasty. The curriculum

error. If the naturalistic treatises of antiquity had been based on careful reflection about the universe of fact then available, the baccalaureate curriculum of the medieval university came to stress the discipline of exposition of texts deemed authoritative and the refutation of opinions about those texts.

This emphasis on the literary side of the liberal learning took different forms but in no way waned during the Renaissance. The critical fact here is that the extraordinary development of the modern experimental sciences from the sixteenth to the eighteenth centuries took place after the fundamental structures of the modern university had been solidly established. By the time of Copernicus, the division of the university into corporate faculties and colleges, its prescription of curriculum, its institution of an examination system, and its division of degrees into the baccalaureate, the master of arts, and the doctorate were firmly in place. And of all human institutions, nothing quite rivals the academic one in its tendency toward rigid compliance with entrenched custom. Thus the great cultural movement of modern science gestated and flourished without making much impact at all on universities until the beginning of the nineteenth century.

In the history of the liberal arts, the sixteenth century stands out as the first period since antiquity in which new rationales for liberal education were explicitly articulated. Propelled by a vigorous critique of what seemed a sterile preoccupation of medieval scholasticism with dialectics, educational theorists of the Renaissance formulated ideals of liberal learning that moved in two major directions. One, exemplified by Rabelais, exalted the all-round development of human capacities, including the omnivorous ingestion of recorded facts. The other, represented by Erasmus, sought to redirect liberal learning toward an emphasis on the third member of the *trivium*, rhetoric. This theory placed the teaching of languages at the center of the curriculum and featured the cultivation of a pure and elegant style by immersing students in exemplary literary works that would develop their taste and provide models to emulate. The subordinate position of natural science in such a program gets exhibited dramatically in Erasmus's statement that: "If we have to study things in nature and their properties this is not in order to understand them but in order to understand the metaphors, comparisons, and stylistic figures of every kind which can be drawn from them" (Durkheim 1977:196). The doctrines of humanist educationalists influenced by Erasmus came to dominate thinking about liberal learning for the next two centuries. Their emphasis on rhetorical form seemed well suited to the needs of young cohorts being prepared to participate in the the refined ways of that polite culture generated by the newly wealthy strata of Renaissance societies.

Even those who questioned the value of an education devoted merely to literary ornamentation rejected the idea of replacing that curriculum with a sound education in science, for science at the time was viewed only as an accumulation of bodies of fact. The possession of such factual treasures seemed nothing more than a different kind of ornamentation, and thus equally useless before what critics like Montaigne held to be the supreme goal of real education: to develop the powers of judgment. And the only serious alternative

sciences as a basis for future engineers and physicians. Despite the efforts of some later educational theorists, like Auguste Comte, to incorporate scientific learning into the fabric of a truly humanizing curriculum, the dominant tendency in France, as in Germany and England, was to retain the notion that classical literary culture formed the proper basis for truly liberal learning and that study of the natural sciences was relevant chiefly for its utilitarian applications. This split perhaps reached its most extreme form in France in the 1850's with the establishment of the "bifurcation system," in which pupils divided into two categories from the fourth grade onwards, some studying the classical languages, the others the natural sciences.

Such are the roots of the contemporary outlook that pits the sciences against the liberal arts when we come to think about education. At the beginning of this century, Emile Durkheim offered the following comment on this dilemma in words that still carry some force today:

It remains true that the function of education is first and foremost to educate the human being, to develop the seed of humanity which we carry within us. But an education whose sole aim is to increase our mastery of the physical universe is bound to fail in this central task. This explains why science teaching still has such low status, and is regarded as of only secondary importance in our educational system. It is seen merely as an optional extra. Cold, languishing and lifeless, it is dragged or rather towed along behind the study of the arts; and hardly anyone sees any inherent link between these two types of discipline. As long as science is conceived of in this way, as directed exclusively towards the external world and to things which have nothing to do with us, it is impossible that the subject will be humanised and revitalised.

But this dichotomy is a false one, which depends on nothing to do with reality but solely on the way in which we conceive it. It is a hang-over from the past. Far from its being the case that between the disciplines which deal with the world of persons and those which deal with the world of things there is a great gulf fixed, the fact is that they mutually imply one another and converge on the same end. It is because people fail to recognize this underlying unity that they can plausibly deny the educational and indeed the moral value of a scientific education (1977:337).

Returning to the present, what could be done to restore the study of the physical sciences to a fully legitimate place in the course of the liberal arts? The question comes precisely at a time when many educators have been struggling to redefine liberal learning in ways that make most sense in our own time.

Let me specify three principles that we at Chicago currently regard as valid for the construction of a liberal curriculum. First, it should provide an informed and thoughtfully articulated orientation to the world and man's place in it. Second, it should cultivate a range of capacities that enable persons to make inquiries, express themselves, and form sound judgments. Third, the liberal

equilibrium, fission, nuclear, and steady-state serve us well both in and out of the social sciences as heuristics for describing and understanding many kinds of human phenomena.

Finally, if the liberal arts are to humanize us by revealing human nature through its manifold historic expressions, then surely there is a whole area of humanity being excluded if we do not attend to the enormous cultural achievement represented by the physical sciences. If the effort to view science in its frankly human guise poses some risk to the sacrosanct status it commonly enjoys, as Steven Brush warned in his witty paper, "Should the History of Science Be Rated X?", the scientific enterprise can only gain by coming in from its cold isolation from the rest of human endeavor and becoming integrated in the liberally educated person's view of significant features of the human career. Among the salient features of the scientific enterprise to be exhibited in this manner, I would stress the significant diversities of view within science about criteria for fruitful research programs, the diversity of positions about aims and methods within particular fields of inquiry, and the ways in which scientists' decisions about what is relevant to study depend on the terms they have chosen to employ, as Joseph Schwab argued so elegantly three dozen years ago in his seminal paper, "The Nature of Scientific Knowledge in Relation to Liberal Education."

If the reasons I have just outlined can be taken as necessary and sufficient conditions for including the physical sciences among the liberal arts in our time, then what implications does that hold for how we should organize the practice of teaching these disciplines in the liberal curriculum? Although I have neither the time nor the qualifications to present a detailed response to that question, I can with some confidence assert that only if general education courses are designed with these goals in mind will they come close to reaching these objectives. That is to say, although a course of study consisting primarily of the conclusions of one or more scientific fields may be quite adequate for a utilitarian program in science, I see no way to justify such a curriculum as part of a liberal program in the sciences. Instead of a survey of empirical conclusions, rather, the liberal curriculum in science should be designed to convey notions basic to a modern cosmology, clusters of material pertinent to human functioning in today's world habitat, experiences that fortify sound observation and cogent reasoning, the diversity of pathways in the scientific enterprise, and the excitement of the scientific calling.

#### REFERENCES

- Brush, Stephen G. 1974. Should the History of Science Be Rated X? *Science*, 183:1164-1172.
- Durkheim, Emile. 1977. *The Evolution of Educational Thought*. London: Routledge & Kegan Paul.