Early American Science and the Roots of Modern Biology

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We in the sciences seek to educate our students in the terms of the general traditions of the past as well as to provide them with the most relative certainties we can select from the ever-expanding fact structures of the thought systems of modern science. Thus, we provide a continuity between generations that makes search for the historical perspective our imperative quest. This continual search for professional growth is perhaps the most challenging task that confronts the teacher. He must seek to master the specific knowledge of his time and to develop the broad perspectives necessary to establish a context in which to present his special information to his students. This presentation must be made in a manner that will assist them to develop within themselves a deeper understanding of the larger context of the historical continuity of man's search for his place in nature.

We realize today that the advance of science depends upon the addition of knowledge and understanding, bit by bit, increment upon increment. It is a fundamental characteristic of the individual research scientist that he concerns himself most directly with the immediate process of science. He is concerned with the demonstration of the certainty of the individual increments of knowledge—facts derived from past sets of observations and which provide the basis from which he can plan to test new observations — to quote Claude Bernard, "The mind of a scientist is always placed as it were, between two observations, one which serves as a starting point for reasoning, and the other which serves as conclusion." Out of such open-ended pursuits comes the synthesis of the new and innovating conceptualizations that lead to new perspectives. (1)

Those of us who have been deeply involved and concerned with the teaching of science have recognized that if we are to communicate effectively, and if we are to give meaning and significance to science as an innovating form of human enterprise, it is essential that we help the student to relate the specifics of the facts systems of science, to the larger and broader spheres of human concern—the individual student invests his energies most deeply, and learns best, when the substantive information which confronts him carries an identifiable relation to his individual being and to his larger concerns—to the formulation of his personal image and his comprehension of man's place in nature.

Bruner describes this realization, "perhaps the most basic thing that can be said about human memory after a century of intensive research, is that unless detail is placed into a structural pattern, it is rapidly forgotten."(2) Factual detail must be placed in a structural perspective if it is to have lasting meaning for the student. The student, after all, like each of the rest of us, is concerned with the basic quest — to increase our information about man and nature and the better understanding of man's place in the natural scheme of things.

It would be presumptive in the short time available here to attempt to provide analysis in great detail either of early American science or modern biology. I thus take the privilege of assuming a fair universality of acquaintance with the details of modern biology on the part of many colleagues here and I will examine the setting in which we find ourselves today and how we have come to it.

Although not often presented as such in the classroom, the discovery of America was a major event in the history of science—perhaps without equal in its total impact on man's conception of the world. It was a highly unlikely event in the first place if considered in the context of the prevailing theories of the world. Old World concepts of climate in the period were patterned after Aristotle who had stated that there were five zones of climate that stretched around the world in an orderly fashion. He divided these zones into the habitable, temperate areas, and the non-habitable areas, of the Torrid, Arctic and Antarctic regions. Based upon such guidance a man could travel, could safely sail his ships to the East and to the West under "known skies," but the risks he assumed were his own if he chose to travel either to the North and to the South. Climate was considered to be consistent within any given latitude around the world. The discovery of the New World with the climatic variations of the East coast disrupted the certainty of these earlier assumptions—all of which encouraged exploration of the Torrid zones and encouraged speculation about possibilities of an Arctic passage to India.

The impact of the new land on man's senses had other consequences as well. The presence of natives (the Indians) and of new plants and animals raised serious questions about the dependability of the Bible as a source-book of natural history. Assuming that the Book of Genesis was truth, where had these natives and these strange forms of life come from? The impact of the new world was that it contained new phenomena unknown to the old world, phenomena that challenged credulity—the humming birds, the macaws, the vicuna, the llama, the skunk, the rattlesnake, the jaguars, armadillos, the turkey, oppossum, the moose, the dam-building beaver, strange fishes, and insects, and monkeys with prehensile tails. The first task to which these newcomers turned their attention was that of setting the record straight. The Book of Nature had to be brought to terms with the "revealed word." They superimposed on this search for natural history all of the preconceptions of both theology and the natural sciences that prevailed in Europe at that time. The facts of the developing natural history were searched for their possible moral significance and consistently used to support theological interpretations at every turn.

Their approach to Nature was all encompassing—They made a sweeping attempt to order all the previously existing knowledge of man and that of his new environment into relationships and descriptive patterns that would demonstrate the "utility" of the information and express man's gratitude to the Creator for having brought it all into being. As late as 1812, the attempt of Benjamin Waterhouse, *"The Botanist,"* is reviewed in the *Medical Repository* and this modest definition was offered—"Natural History may be termed from its vast and almost unlimited extent, a nomen generalissimum; a term comprehending a cluster of sciences, and a grand aggregate of knowledge. Botany, Mineralogy and Zoology are three of its branches; and Medicine, extensive as it is but an appendage to Zoology containing the history of the diseases to which animals are subjected: unless, indeed, the maladies of plants be considered as referable to the same." (3)

These naturalists as they went forth into the wilderness, facing deprivation and even death were bent on perhaps the great enterprise of all time—the grand attempt to assemble a complete catalogue of information on the world's phenomena. The observations and descriptions that would come from their efforts would eventually establish that first great body of information which could be called science, complete with all its errors, and discontinuities, and inconsistencies. The prevailing tendency of the time was to ignore and to set aside as curiosities those facts and observations that were inconsistent with the written word; however, this approach to knowledge would eventually be replaced by man's reasoned recognition of the need to seek meaning in nature by bringing his attention to bear on the significance of the inconsistencies and the variations observed in patterns in nature. This could not occur until a significant body of knowledge was established. And this was the work of the early naturalists. I regret that it is not my privilege in this paper to treat them as fully as they deserve. The writings of such men as Joseph d'Acoste on Central America, Thomas Hariot and William Strachey on Virginia, William Wood on New England, to name a few, contributed much to the intellectual ferment of the time. Later came Mark Catesby on the Natural History of Carolina, Florida, and the Bahama Islands, and perhaps most influential of all were John and William Bartram, the father and the son whose writings have become literary classics as well.

Despite the general consequences of their work, we must agree with Smallwood who says, "Few Naturalists made profound discoveries or lasting generalizations." (4) Their problems lay in the fact that their efforts were directed toward making their observations compatible with the philosophic interpretation of nature that prevailed at that time—a world descendent from Genesis and a world without change. New information was used to support the older, established interpretations. It was not until mid 19th century that American scientists would begin to be more free and to develop more flexible philosophical positions and interpretations of nature derived from the observations which they made.

There was a further often unnoticed impact of the discovery of the New World and its wilderness, which though a thing of beauty to the naturalists, was a threatening disruptive force to most of the early settlers. The Colonies experienced a rapid breakdown of the traditional cultural patterns inherited from European Society. As Bailyn describes it, "In the course of adjustment to a new environment, the pattern of education was destroyed; the elements survived, but their meaning had changed and their functions had been altered. By 1800 education in America was a radically different process from what anyone in the early seventeenth century would have expected." (5) The patrilineal family based upon "extended kinship gathered into a single household" had been the "most important agency in the transfer of culture." With the disruption of the stability of the family by the forces of migration and wilderness, the Colonists soon recognized the urgent need to move through public agencies to the support of education "lest they and their children succumb to the savage wilderness—lest the rude son strike father dead." (6) In the 1740's Virginia and Massachusetts passed the first American laws on education, thus demonstrating their concern for the education and training of children and the need to strengthen the family unit. The education laws of the next hundred years continued to reflect the disruption of the family — "the isolation of the conjugal unit," "the reduction to the nuclear family," (7) and the need to turn to the larger social unit, the community, to support the transfer of culture from generation to generation. This sequence is approaching climax today in America with the level of education, and particularly the new role of science as a social force, being recognized and demanding national and international attention as an essential to survival. The community must provide what is beyond the capability of the family.

In the South, Virginia et al., the awareness of the same problems was acute but "lacking the reinforcement of effective town and church institutions, the family was even less resistant to pressures and sustained even greater shocks." (8) Contrast this with the conditions in New England which possessed a high cultural level, Puritan dependence upon the Bible, concentrated settlements and town governments that were well knit. The Puritans transferred the fragments of the shattered family educational patterns to formally structured institutions of learning. And in so doing, they defined responsibilities in vocational, cultural, and moral training of the young for these new institutions that are still developing in our country and which have had profound effect on American science.

The analysis of Puritan thought by Perry Miller in the *New England Mind* provides us with insights that help us understand how extensively the Puritan religion has influenced American science. The Puritans derived their ideas from the Bible, from St. Augustine, Calvin, Ramus, Perkins, and others. They believed without question that the Bible was the Word of God and they were "of the Word"—they were also "of experience" in the world as well. "Look," says the Puritan preacher, "the doctrine is 'as in nature, reason teacheth and experience evidenceth;' to deny it 'is to go against the experience of all ages, the common sense of all men.'" (9) The world as they saw it, "could not make itself, so neither could it continue itself in being; if the power which made all creatures did not preserve them, they would presently return to the first nothingness." (10)

Such an assumption called for more than a "blind vitalism." It was the Puritan conviction that "God not only gives being to the world but, Himself the supreme intelligence, directs it to intelligible ends." "God's government must by definition consist not only of 'sustentation' but also of 'Direction... whereby He orders everything to its right end.'" (11) This is the doctrine of Providential determinism—a world of certainty, a world without change. And it was an imperfect world in which man by pursuit of knowledge could know God better and bring it and himself nearer to the original state of perfection. (12)

As John Cotton preached it—"To study the nature and course, and use of all God's works, is a duty imposed by God upon all sorts of men; from the King that sitteth upon the Throne to the Artificer; there is a settled order in this variety of changes, as in the motions of the Heavens and it is the duty of the pious man to find out if he can." (13)

Thus knowledge of nature (I'll call it science) was "not merely tolerated" but was "actually advanced as a part of faith itself, a positive declaration of the will of God, a necessary and indispensable complement to Biblical revelation." It was with this in mind that Charles Morton is cited from the *Compendium Physicae,* a famous physics text at Harvard College, "'tis natural Theology, that men should be industrious in natural philosophy." And with these motivations men bound the "beauty" of nature with its Providential and profitable use — beauty and utility became one—beauty was "the perfection and congruence of one thing with another" and could not have existence or a value in and of itself. This fundamental and limiting concept of utilitarianism reaches into every American classroom today. How often has basic research, the search for fundamental knowledge, been described as "What you do when you don't know what you're doing." And consider the debates on the part research experience should play in the classroom. (14)

This Puritan science I speak of here is not the same as that which we call modern science. As has been described, their science was subservient to theology, the medieval queen of the sciences. It was a simple science which looked upon imagination as an indulgence in vanity. Their science was God-given, simple and open to the humblest intellect. Through pursuit of their science, man could have an experience with the Mind of God, direct, unquestionable, and without variation from one man to the next. All men were scientists in part at least, struggling together to read the Book of Nature and to sift the phenomena for their religious implications.

The early Puritan had inherited a God of Wrath—vindictive and wrathful toward man the sinner. And events in nature were interpreted in that view. Donald Fleming sees the Englishman, Thomas Burnett, speaking for the God of Wrath in his *Sacred Theory of the Earth* published in 1681. Burnett described the world as a place of evil with atmospheric phenomena, lightning, storms, comets, and the like as evidence of the smouldering rage God felt toward men. Increase Mather in New England agreed with Burnett and called the Comet of 1680 "a token of God's Wrath." He predicted the Day of Judgment for about 1700 when Christ would come again and purify the world with fire. In 1683 in his *Kometographic,* he claimed that comets had caused the Boston earthquake.

Within one generation, however, there came a modification of Puritan thought. Robert Boyle, the chemist in England suggested that it was a God of Love who had established all nature for man's benefit. Sir Isaac Newton disturbed the Puritans further by pronouncing in the *Principia* that comets might have positive effects on the earth—stimulating the flow of the watercycle, keeping the earth watered, green, and thus insuring life.

Cotton Mather (the son of Increase) published the *Angel of Bethseda* (1724) early in his career. He therein related disease to the "just workings" of Providence. He set forth a theory that disease was punishment for particular sins of the particular part of the body. A ministerial review of your transgressions anatomically would bring the evil sin to the fore and through contrition, health could be restored. The God of Wrath had received his due.

Cotton Mather could not escape the in-stability of the new world. He, himself, joined the forces of change. He modified his earlier assumptions about catastrophe in Nature and shifted his allegiance to the God of Love. This is most evident in his well known work in the smallpox epidemic in Boston. By organizing the first large-scale inoculation experiment in the New World he became the first man to attempt the scientific management of a disease. In so doing, he broke with the deterministic Puritan science, and he moved to give man control over what earlier Puritans and man in general had felt was the inevitable extension of the hand at the God of Wrath. Fleming has described the consequences—"From that time forward man no longer dealt humbly with a God of Wrath who was without mercy. Man's problems of the past had been the visitations of a Providence that was not to be questioned. His problems now were his own—man could use the knowledge of nature to control his own future. The responsibility for decision was now his own." (15)

This defined a new status and responsibility for the individual in a new philosophical schema, one which gave him freedom to develop knowledge in a less rigid world view. The individual no longer dwelt in a world of Providential certainty in which consequences were accepted without question. But he likewise no longer dwelt in a world possessed of complete guidelines for moral purpose based on science that unified his community and in which some daily contact with science was the responsibility of every man. This unity and the traditional image of the individual in society disappeared in the face of the new freedom. This erosion of the early Puritan form of science and the American Revolution fairly well closed this unique but influential period in our history.

Bailyn tells us the educational institutions created by the Puritans passed through the Revolution without much change. (16) We know that the science changed greatly in substance and goal. Gone was Puritanism to dictate the course it would take. Gone also was the public commitment to its value and importance. Perhaps the most important influence that remained with us was the fragmented interpretation of Puritan utilitarianism.

As we look for the roots of modern biology in this history, it becomes clear that one of the real problems in our development has been this concept of Puritan utilitarianism lifted out of the context of the deterministic world in which they had lived. For them, the pursuit of utility in society and in nature had meaning as an end to knowing God's world. Removed from this context, our subsequent pursuit of utility for no purpose other than its own, or limited economic consideration, has legislated effectively against the development of either schools, science or biology dedicated to the beauty of new knowledge and to its capacity to assist man to increase his understanding and thus to enable him to better relate to an environment in constant flux. This was the effect of "Yankee Utilitarianism"—this was as well the "ethic of useful work" which still determines our social values and language as Galbraith says we "invest" our money in roads and bridges but we "spend" on education.

Science did not seriously rise again in the American public mind as something which should concern the mind of every man until our own day. Science did not come to prominence in America until our national educational policies were challenged from outside our culture and this took nearly 150 years to happen. The social setting of the Puritan which integrated science into their culture as an element of intellect has yet to be re-interpreted and accomplished in our own time.

The social setting in America for 19th century science was weak. Revolutions in other nations left them with a more positive support of science. However, in America, although we continued to see refinement and increased precision of method in natural history, our contribution to either biology or science was not great. Willard Gibbs in physics is our greatest man of the period and he received his stimulus from experiences in Europe. It was a characteristic of the century that while we were settling the West, a Europe free of our peculiar form of utilitarianism produced the major advances in biology and science.

The new world view in geology removed the comforts of static creation and placed us in a world of flux. The theory of evolution, a culmination of natural history, removed the certainty of individuality and made us all dependent on chance determination of events that had little bearing on Providence. Application of physics and chemistry to the cell emphasized the dependence of individuality upon forces of an impersonal and perhaps indifferent nature. The germ theory of disease gave man his first opportunity in human history to manage disease.

These advances led millionaire philanthropists in our country to controvert the very utilitarian traditions by which they had wrested their wealth from the earth. They emulated the patterns of European education and established the first American university graduate schools with real dedication to the production of new knowledge. John Hopkins, Leland Stanford, Ezra Corwell, Andrew Carnegie, and John D. Rockefeller legitimized personal involvement with the production of new knowledge as no one else could have done—including the government.

Eric Ashby says "The social pre-requisites for the survival of science are finance, leisure, and freedom to pursue research, coupled with opportunities for scholars to associate together and to transmit ideas and techniques to their successors." (17) Such circumstances once established in the new American graduate school soon brought new knowledge and a series of discoveries, which have shifted on thinking still further from the earlier static world view; the physical basis of heredity, the chromosome, was firmly established by T. H. Morgan and others by 1912. By 1926, H. J. Muller had demonstrated the disruptive effect of radiation on the chromosome. Walter B. Cannon had established the dynamic physiological character of the individual. The continuity of flux and change that had been demonstrated in the exterior world now became evident within the individual himself. Modern biology became concerned with rates of change and the dynamic character of physical events. And presently, we are searching for more information at the molecular level of life—searching for the "codes" of information that define the character, the dimensions and potentials in space and time of both the individual and his species. Contemporary biology concerns itself with phenomena as directly as possible and which are verifiable between qualified observers. Every attempt is made to exclude any dogmatic or authoritarian super-imposition of view upon the phenomena a priori — this is in reverse to the early Puritan.

And finally we are confronted again with the grand scheme of things—man's place in nature—our search for information and understanding of our environment and our impact upon it. Its management is now our responsibility and our decisions determine the future of the major species.

Most of Puritanism and their special form of science is gone from the American scene—yet certain elements still remain.

As we look about us in biology and science, we can agree that we are just now coming out of a period in which science was taught with an encyclopaedic approach as a "body of knowledge" with very limited concern for the intellectual process which brought it into being and with little feeling for the tentative state of present knowledge. This is a vestige of the cataloguing approach of the early natural historian. Many of us still feel uncertain about what is the proper balance of factual information to be learned by the student and the amount of individual experience with science as process he should have; and when in doubt we lean toward the descriptive informational approach.

Most of us will agree that those areas of science that are receiving adequate support in contemporary America still lie in fields considered to be most practical and of great utilitarian value—areas related to medicine, health, and national defense.

We recognize that most people mistake technology for science and have little understanding that science as process, as a search for new knowledge, is of much greater importance and significance than the material products that fall from its forward motion.

These are the circumstances in which we find ourselves today. We must understand their historical roots and context if we are to attempt their solution. We have come far and we truly live in a new world—a world in which we as scientist-teachers (and others as well) must give as much attention and devote as much concern to the meaning and the purposes of the philosophical setting in which we work as we do to the beauty of the new knowledge that is produced. This has not been true enough in the past, but as our concern grows, so will our willingness to act upon it.

The need for heightened concern lies in the fact that science has again become a social institution. It is however, operating on different value scales than most of the rest of society. The essence of contemporary science lies as much in its intellectual processes and social setting, as in its facts, and we must teach it accordingly if we wish to say that we are part of the science of our own time.

References and Notes

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11. Op. cit., p. 15.
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14. Op. cit., p. 215.
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New England Efforts

New England state universities have been urged to give new emphasis on the growth and development of the region's natural environment. Two economists who made a two-year study for the New England Board of Higher Education urged the schools of agriculture in the six land-grant state universities to accept the fact that there will be fewer farms and farmers in the future and aim their research, education, and leadership development programs at a broad array of natural resources and their role in the region's economic and social development.

Among their recommendations: Revise the four-year college program toward providing basic training in the tools of analysis and thought for the natural sciences, social sciences, physical sciences, and humanities. Specialization in courses related to agriculture, forestry, water management, wildlife, recreation, land use and management should begin no earlier than the junior year. Develop graduate studies and research, in part concerned with agricultural production, but also to include watershed management, recreation, land management, wildlife management, regional planning, economic development and training for work abroad in foreign aid programs.

Malaysian Carp

The Bureau of Sport Fisheries and Wildlife is keeping close watch on the feeding habits of 27 small imported fish now living in experimental ponds in Stuttgart, Arkansas. The Malaysian grass carp reportedly prefer a diet of grass and other aquatic vegetation to insects and competing fish. Researchers hope the foreign fish live up to their reputation. Most of this country's farm ponds are plagued with excessive vegetation. Heavy weed growth provides too much escape cover for small fish, the main source of food for larger fish. Vegetation also impedes navigation, swimming, and harvest of desirable fish. Malaysian grass carp may be one solution to these problems, provided they reproduce satisfactorily and will not adversely compete with other species of fish or eat desirable waterfowl foods.

Drivers: Take Heed

Highway accidents in the U. S. took a record number of lives in 1963. The 42,700 fatalities reported by the state motor vehicle departments, and compiled by The Travelers Insurance Companies, surpassed the 1962 count of 40,500. In addition, more than 3,460,000 persons were injured in 1963. Of these figures, 34,700 deaths and nearly 3,000,000 injuries were blamed on driver error and lack of judgment.