THE AMERICAN SCIENTISTS AND THE RISE OF THE ELECTIVE PRINCIPLE

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The following is neither a well-balanced account of the development of ideas on science nor a chronological description of the implementation of the elective system in American higher education around the middle of the nineteenth century. Rather, this essay tries to ascertain the interrelationship between these two seemingly independent phenomena. In so doing, the author wishes to locate the rise of the elective principle within the broader context of the transformation of science. In other words, he wants to restore a few of those now-forgotton scientists who actually played an indirect but important role in the introduction of the elective principle in the colleges and universities of the period. [1]

A few historical facts prompted this approach, along with the relative emphasis on the history of science in recent historiography. [2] Although primarily remembered today as an educational reformer in higher education, with special reference to the elective principle, Charles W. Eliot was a scientist who emphasized applied chemistry. After some nine years of teaching at Harvard, Eliot as a young scientist had to resign, against his will, from the University, and he spent a few critical years in the newly founded Massachusetts Institute of Technology before assuming his forty-years of presidency in his Alma Mater. Again, contrary to our assumption that Eliot must have continuously insisted on the elective principle, his famous 1869 article pronounced something exactly the opposite in relation to the explanation of the academic and curricular organization at the Institute of Technology. How can we combine these facts to produce a viable picture on the origins of the elective system, especially in relation to Eliot's early career as a scientist at Harvard and at the Institute of Technology?

The present essay is based on the hypothesis that the movement largely originated in the changed nature of scientific inquiries and its impact, through the changed ideas of culture, upon the contemporary colleges and universities. Whence the said change in scientific inquiries? What were some of the characteristics of this change? How did they affect the old ideas and organization of college education? Our inquiry will start with the Smithsonian Institution and the ideas of its first Secretary, Joseph Henry.

I

In 1829, James Smithson, an English scientist who had regarded himself a cosmopolitan, died in Italy, leaving his property as a bequest to the United States "to found at Washington an establishment, under the name of the Smithsonian Institution, for the increase and diffusion of knowledge among men." [3] However, almost seventeen years passed before the incorporation of the Institution in 1846. The delay was partly derived from the varieties of conflicting suggestions concerning the use of the fund, which ranged from a post graduate university, an astronomical observatory, a normal school, to a library, an institute for the promotion of agriculture, and a mineralogical bureau. Each had behind it a dedicated body of interested persons.[4]

When the Institution was incorporated in August 1846, the whole scheme was oriented toward the establishment of a comprehensive library.[5] By the beginning of 1847, a shift in emphasis took place with the ascent of Joseph Henry, professor of physics at Princeton, to the directorship the year before, when the Board of Regents of the Institution decided to divide the interest from the fund in equal portions ; one half for the library, the museum, collections, & c., and the other half for the stimulation of original research through publications and aids.[6] Furthermore, six years later, Henry's majority group in the Board sought to establish the rule that in the future the Regents should apportion, upon their own judgement, the annual appropriations specifically among the different facets of the Institution.[7] In the midst of this movement, Rufus Choate, one of the minority of the Board and himself the promoter of the library plan, resigned from the Board of Regents, an incident which stirred debate within the Senate. In the letter of resignation, Choate openly accused the Board of Regents of digressing from the original objectives established by Congress and devising their own, thus "building up an institution substantially unlike it (Congress) intended."[8] Charles W. Upham, Choate's friend in the House, summarized the position of the minority in the following way :

> The word 'INCREASE' is held by some zealous combatants in the Smithsonian controversy to be identical with 'DISCOVERY'. The idea seems to be that knowledge can only be *increased* by the *discovery of new truth*. This is an arbitrary and untenable position. A mind experiences an increase of knowledge if it knows more than it did before, although

> all the ideas it has received may be in the commonest text-books. There has been an increase of knowledge in the school, in the congregation, in the lecture room, if ideas not before known to them have been received into the minds of the hearers... The language of Smithson is perfectly simple... it includes, but does not require, *new* truth. Truth dicovered thousand years ago is as good as truth discoverd yesterday. Knowledge embraces it all alike, and Smithson's object was to carry knowledge where it was ; to spread it over a wide area, and to a great depth. [9]

Upham contended that the increase and diffusion of knowledge could well be identical. The minority's support of the library plan rested upon this ideology.

In December 1847, against such a stand, Joseph Henry set forth his idea of the organization's two objectives : to increase and diffuse knowledge among men. "These two objectives," he held, "should not be confounded with one another. The first is to enlarge the existing stock of knowledge by the addition of new truths ; and the second, to disseminate knowledge, thus increased, among men." [10] In the following year, Henry again touched on the two objectives, saying "that the terms *increase* and *diffusion* of knowledge are logically distinct, and should be literally interpreted with reference to the will, must be evident when we reflect that they are used in a definite sense, and not as mere synonyms, by all who are engaged in the pursuits to which Smithson devoted his life." [11] Henry was not opposed to the diffusion of knowledge. Yet, the mere juxtaposition of "increase" and "diffusion" lent support to the library plan. In this dilemma, while retaining the two objectives of the Institution,Henry sharply distinguished between increase as diffusion and increase as advancement, and thus argued against the minority's stand without getting himself into a difficult situation.

How was Henry's distinction justly derived ? His answer here would be almost identical with his definition of scientific studies, a definition stemming from his experience as a pioneer experimental physicist. "The Plan of Organization" prepared by the Institution in 1848 stipulated that its Memoirs would reject "all unverified speculations." [12] The provision invited debate on whether the Institution justly valued abstract speculations. Henry answered that all the advances in true science were preceded by well-conditioned hypotheses which were by nature speculative. However, in order to make themselves authentic, these hypotheses needed verification through vigorous experimentation and observation. In Henry's words, "it is the exact agreement of the deduction with the actual result of experience that constitutes the verification of an hypothesis, and which alone entitles it to the name of theory, and to a place in the transactions of a scientific institution."[13] With the incorporation of this process of verification into the methods of inquiry, the increase of knowledge began to assume its distinct place from the dissemination of acquired knowledge.

The criticism from the minority, however, queried the value of knowledge thus gained as well : was verified knowledge better than knowledge stored in books simply by virtue of its exactness ? In their effort to diminish the library plan, the majority of the Board pointed to the consequence that accrued from the cultivation and dissemination of that kind of knowledge within the present context of social life :

> The most important, valuable, and productive of the art of

> life, the most important and wonder-making inventions of modern times, owe their being and value to scientific investigations. By these have been discovered physical truths and laws, the intelligent applicaion of which to practical invention has given immense benefits to the world. [14]

To make their argument more specific, the majority referred to the field of research which Joseph Henry himself represented :

> The discovery that a magnetic needle could be moved by a galvanic current, seemed for a long time more curious than useful, and yet it contained the germ of all that was afterwards developed in the telegraph. It has been always result from the discovery of a scientific principle ; so that there are many Fultons for every Franklin. [15]

Thus, in the majority's argument, a major difference between "new truths" and the old ones lay in the applicability of the former to socially useful inventions. By pointing to the "contemporaneous advance of science and art, and the dependence of the latter upon the former for the improvement of its most important progresses," the majority emphasized the superiority of scientific knowledge as a means to control and exploit systematically natural forces and resources for social benefits. [16]

These two aspects of "new truths", their verifiability and applicability, were manifested in Henry's early career as an experimental physicist. In particular, Henry's electro-magnetic experiments during the early 1830s had some practical implications, the major goal of which was the construction of powerful and efficient magnet as possible, as well as the production of "the greatest magnetic force, with the smallest quantity of galvanism." [17] His experience as an experimental scientst, in addition to his broad social vision, helped mould his notion of the special role of new scientific knowledge. The conflict between the two groups over the objectives of the Smithsonian Institution in the 1840s offered him the chance to express his views by giving a special meaning to the term "increase" of knowledge. "In order that civilization should continue to advance," held Henry, "it therefore becomes necessary that special provision should be made for the *actual increase* of knowledge, as well as for its diffusion ; and that support should be afforded, rewards given, and honors conferred, on those who *really add* to the sum of human knowledge." [18]

II

Henry's position and statements were supported and supplemented by Alexander Dallas Bache, one of the majority of the Board of Regents. A graduate of the National Military Academy at West Point, Bache had taught at the Academy and at the University of Pennsylvania and had done research on terrestrial magnetism and heat before becoming the Superintendent of the United States Coast Survey in 1843. From the very beginning of his scientific career, Bache was dissatisfied with conventional scientific studies at colleges and universities, and he did not rest satisfied with "merely imparting knowledge obtained by the labors of others, but sought to enlarge the bounds of science by discovering his own." [19]

Like other leading American scientists of the time, including Joseph Henry and William B. Rogers, Bache spent little time elaborating his views on the general nature of scientific research. But a few of his essays addressed a broader audience in the field of science. One of these rare occasions was his retirement from the presidency of the American Association for the Advancement of Science in August of 1851, where his pronouncements reflected Bache's experience as an experimental scientist.

Speaking in the middle of the century as the second president of the earliest, nation-wide scientific organization of general scope, Bache first characterized the changed nature of scientific pursuits, and then compared it with some of the obstacles hampering the advancement of the organization. Bache described the type of scientific studies prevalent in the United States during the late eighteenth and early nineteenth centuries as being emphatically marked by descriptive natural history. The prosecution of mathematics and physical science, which had been cultivated earlier through frequent contact with British scientists, was only barely kept alive "by the calls for boundary and land surveys of the most extended class, by the exertions necessary in the lecture room, or by isolated volunteer efforts." Now the constellation was altered overtime. "The calls for mechanical knowledge, and for the applications of physics, of mathematics, and of natural science, have, whithout a doubt, thrown us irresistibly into the career which we are now following, and which, in its objects, aims and results, partakes of the general direction of the science of the world." [20]

In spite of this, American scientists failed to articulate the new objectives of research as well as to cultivate those new dispositions necessary to carry out new missions in science. As a result, there prevailed the old ideal of universal culture and the respect for lecturing and manners :

The absence of a minute division in the pursuit of science,

> the prevalence of general lecturing on various branches, the cultivation of the literature of science rather than of science itself, has produced many of evils under which American science has labored, and which are now passing away... While a general knowledge of various branches of science is useful in developing even a single branch, it is still certain that subdivision is essential to advancement. An Admirable Crichton rather fixes attention to his *own* perfection, than perfects any art. [21]

Until now, students had learned science primarily for personal refinement. This time, they would have to devote themselves to the perfection of a special branch of the science, however limited it might be, even at the expense of an all-round culture.

Along with the sense of objective, the habits or dispositions of the men of science needed transformation. Bache set forth his image of an ideal scientist in his depiction of the character of George Bache, his brother who had drowned while engaging in the study of the Gulf Stream in 1846. "Remarkably fertile in expedients for experiment, delicate in the use of instruments, careful in observations, ready in classifying facts, persevering in their accumulation, apt at generalizing, his mind glowed brighter and brighter as he entered into a course of experiment and observation." [22] Many of the members of the Association, particulary those from the colleges, lacked those traits required to strive patiently to expand the boundary of knowledge. This deficiency partly stemmed from the enthusiasm for popular science in mid-ninteenth century America. Bache's negation in this sphere was rather categorical :

> Lecturing is, of all the arts, one of the most easily acquired, at least by our countrymen ; it is undoubtedly useful, and

> most agreeable, but should not be the object and end of a man's career. It is not necessary to found institutions especially for its encouragement: nor should the power to diffuse science in succeessful courses of lectures be considered as a substitute for exertion in its advancement.[23]

As could be expected, in his address Bache put emphasis upon applied mathematics and physics, in which he had considerable background and experience, to the relative neglect of the biological sciences, whose increasing significance in popular science was, he believed, hampering the advancement of the physical sciences.[24] A similar consideration on Bache's part was reflected in the proposed creation of a government-funded, national organization of scientists, the future National Academy of Sciences.

There still was some hope for the American Association. Among the members of the organization, the geologists possessed the disposition and the sense of objective needed by men of science. Referring to their contribution to the consolidation of the Association, he stated:

> The geological surveys making in several States rendered meetings of those engaged in them very necessary, for comparison, discussion, systematic effort; for counsel, aid, and mutual improvement... In that association, positive work was the test of consideration; to be heard, a man must have *done* something; and the more he had done, the more patiently he was listened to. Thus, far deeper, morally, than the comparative depths which they explore, the geologists laid the foundation of the American Association.[25]

It seems certain that, when he thus praised the role of the geologists, Bache had William B. Rogers, then General Secretary of the Association, in mind as one of the most prominent of them all.

III

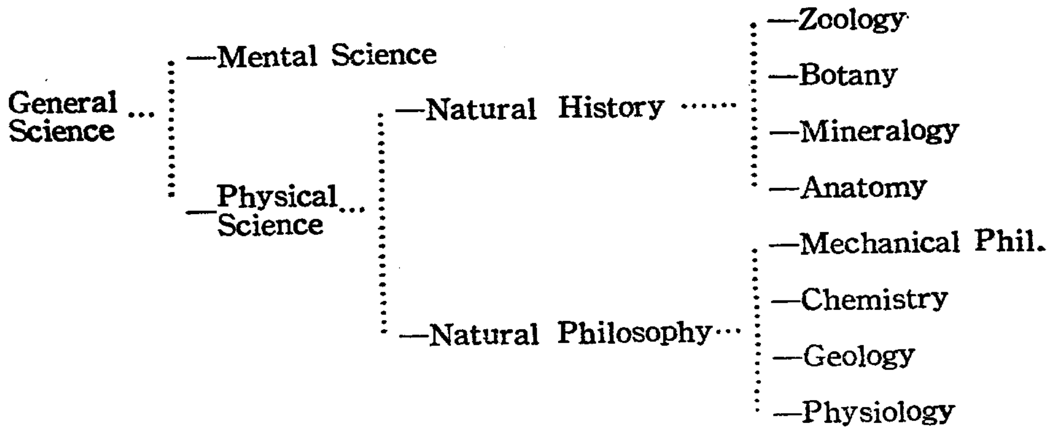
As Ralph S. Bates pointed out, "most American scientists in the first half of the nineteenth century did not find their careers as instructors in the colleges."[26] In this respect, Joseph Henry, Alexander Bache, and William B. Rogers were all exceptional. Joseph Henry (1799—1878), the oldest of the three, became Professor of Natural Philosophy at Princeton, then the college of New Jersey, in 1832. William B. Rogers (1804—1882) succeeded his father at William and Mary College in 1828 as Professor of Natural Philosophy and Chemistry. Alexander Bache (1806—1867) was appointed Professor of Natural Philosophy and Chemistry at the University of Pennsylvania in 1828. Again, invariably, all three disconnected their affiliation with the universities around mid-century, partly because they were not fully satisfied with the conditions of scientific studies obtainable there, and partly because their personal contributions were sorely needed for the newly emerging scientific institutions and nation-wide associations. Joseph Henry and Alexander Bache, for example, served as the second and third presidents of the American Association for the Advancement of Science respectively, while William B. Rogers drafted its Constitution.[27] Moreover, Bache, Henry and Rogers were the first three presidents of an equally important national organization of elite-scientists, the National Academy of Sciences, established in 1863.

These similarities should not obscure important differences in their respective careers. Henry's major concern remained with the management of the Smithsonian Institution. After 1843, Bache had devoted himself to the completion of the coast survey. In contrast, Rogers embarked on an adventure in the founding of the Massachusetts Institute of Technology. Again, Rogers' connection with reform in higher education was more direct than the case of Henry or Bache, since it was Rogers who lured Charles W. Eliot from Europe in 1865 and appointed him Professor of Analytical Chemistry and Metallurgy in the Institute. After four years of service under Rogers, Eliot left the Institute to become the president of Harvard in 1869, the seat of university reform in the late nineteenth century.

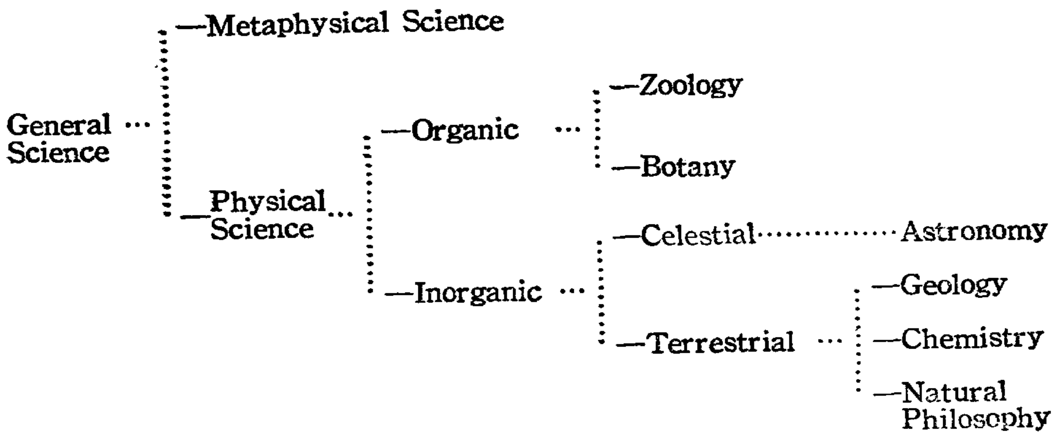
The four scientist-Rogers-brothers (William was the second oldest) were largely educated at home by their father Patrick Rogers, a political refugee from Ireland and Professor of Natural Philosophy at William and Mary College from 1819 to 1828.[28] Reflecting in part the training thus received, William B. Rogers showed, in the words of the father to Thomas Jefferson, "a very extraordinary passion for physico-mathematical sciences."[29] Although William's interest comprised almost all the branches of Natural Philosophy, applied mathematical mechanics stood out as the most enduring, particularly as the major subject of his teaching. In 1838, he published a textbook in this sphere entitled *An Elementary Treatise on the Strength of Materials*, "the first American book in this field."[30] Rogers transferred the basic scheme of this 1838 treatise to his 1852 textbook, *Elements of Mechanical Philosophy*, a far more theoretical and systematic, but equally practical work. Here Rogers expounded the principles of Mechanics as they apply to both solid and liquid bodies in view of their ultimate service to production and transportation.[31]

Rogers' preoccupation with geology made his scientific career somewhat distinct from that of Henry and Bache. The Geological Survey of Virginia, begun under his leadership, brought Rogers and his brother Henry D. Rogers to major areas of the state as well as to neighboring states for the purpose of field research. By the time the brothers, with their broad background in Natural Philosophy, presented their interpretation on the formation of the Appalachian chain before a meeting of geologists in 1842, Rogers' geology fully exhibited dynamic qualities, since it utilized the principles of physics in explaining geological phenomena.[32] The historical circumstances of the mid-nineteenth century, however, inspired Rogers, unlike Henry and Bache, to cross swords with a peculiar position in popular science derived from a particular version of natural history then in vogue, a version which had a strong committment to the alleged fixity of species of animals and plants. The critical test of the position lay in geological facts,[33] and, with his knowledge of geological formations and on the fossiles contained in major strata, Rogers was inevitably involved in a debate over Darwin's theory around 1860.

Thus, as might be expected, Rogers' drastic, or even one-sided, criticism of some aspects of natural history from the point of view of natural philosophy separated him from Henry and Bache. In the first chapter of his *Elements of Mechanical Philosophy* of 1852, William B. Rogers presented the following as the basic classification of the various branches of physical sciences:[34]



Joseph Henry published a syllabus of his physics lecture in 1857, in which he propounded the following system of sciences :[35]



Concerning the first division of general science into the physical and the mental or metaphysical, Rogers and Henry agreed completely. The major differrence between the two diagrams appeared in their sub-divisions. In Henry's scheme the first division of physical science was based on the distinct qualities of the object of study, namely organic and inorganic. Spatial locations of the object, such as the movements of heavenly bodies for astronomy, and earthly matters for the others, in turn effected the further sub-division of the inorganic sciences. Similarly, Henry divided the organic sciences into two : zoology as the study of animals, and botany as the study of plants. In contrast, the dichotomy of Natural *History* and Natural *Philosophy* held the key to Rogers' diagram. In this scheme, both *Natural* History and *Natural* Philosophy included the whole range of nature respectively. The methods with which the scientist should approach these objects mattered in Rogers' system. The historical method ultimately aimed at the "classification of objects," while the philosophical one, the "discovery of laws according to which the various changes of the material world are produced." [36]

Seen against the historical background of American science in the 1850s, the two diagrams represented two distinct evaluations of the degree of development among the major branches of physical science. Making recourse to different qualities or locations of the object of study for the purpose of classification, Henry seems to have assumed the invariable applicability of scientific method to all branches. In contrast, Rogers' diagram introduced a sharp distinction between Natural History and Natual Philosophy as two distinct modes of scientific inquiry with different methods and ends-in-view. Moreover, Rogers' diagram pointed to the existing inequality between the two groups of sciences in terms of the degree of their advancement. Among others, zoology and botany as he saw them in 1852 America could not be on the same rank with mechanical philosophy, chemistry, or geology.[37]

A few years after the publication of *Elements of Mechanical Philosophy*, Rogers had an opportunity to elaborate on his discrimination between natural history and natural philosophy as well as on its implications. In April 1855, when he was already in Boston, Rogers accepted an invitation from the Lyceum of Natural History of Williams College to present his interpretation of the recent trends in physical science. Rogers first pointed out that the major task of Natural History had consisted of a classified arrangement of organic and inorganic beings in accordance with their external features and structure, a study of their statical aspect. The recent advancement of Natural Philosophy, however, rendered other principles of classification more significant. As a consequence, Natural History would have to strive, with the aid of related knowledge, to investigate general laws in organic and inorganic beings. In such an inquiry, direct observations aided by the tools of Natural Philosophy would replace published books as the source for classification and nomenclature.[38]

Scientific inquiries thus required a reorientation. Emphasis had previously been placed upon the classification and distinction of things and beings in terms of their external characteristics. As a result, "scientists" had earnestly sought after those things remote, conspicuous, and rare. The development of Natural Philosophy slowly changed the nature of scientific inquiry. With more emphasis upon the investigation of the modes of interaction among apparently separate phenomena, the attention of scientists had to turn to treasures nearer and even immediate around them. "There is scarcely a plant or animal, however insignificant in appearance, that will fail to disclose to your well-directed microscope, features of structure and organic affinities hitherto unknown." [39]

For Rogers the meaning of romanticism and of the esthetic characteristics of Nature was to be transformed. For it was "less in the magnitude and distance of the objects than in their mutual activities, their harmonious arrangements and their adaptations to wise and beneficent ends, that material phenomena became imbued with a spiritual and poetical significance." [40] There was his perception of the changed way of access to Nature, particularly notable in the experimental branches of Natural Philosophy, that demanded a basic reorientation on the part of traditional Natural History. And for Rogers, this perception was identical with his awareness of the utility of science. The new methods of scientific inquiry were, by their very nature, destined to exert a great transformation in our living environment.

IV

In mid-ninteenth century America, notably in New England, a strong enthusiasm developed for natural history, an enthusiasm which had a dual character : religious, since it posited a faith in an unshakable, divinely-inspired natural order ; but, at the same time, scientific, since it sought the evidence of religious truth in first-hand inquiries into nature. Due to contemporary discoveries in geology, which largely discredited Carl Linnaeus' system of natural history, George Cuvier's catastrophism, updated and more sophisticated, inspired natural-history studies as a scientific defence for traditional religious doctrines.[41] The ever-stronger challenge from the physical sciences, however, had the effect of making the first aspect of the enthusiasm dominant, the proof of order in nature. Antagonism grew between Natural Philosophy and Natural History, and the former was virtually precluded from the mainstream of activities of natural history societies. The Boston Society of Natural History, a representative center of scientific studies in mid-nineteenth century America, offered the stage for the emerging conflict between the two approaches.[42]

In his annual address as president of the Boston Society in 1853, J. C. Warren mentioned the powerful impulse the Society had received from some auxiliary colleagues. Of these persons, he specially cited two men, both honorary members, who made notable contributions. One was Louis Agassiz, Professor of Zoology and Geology at Harvard, and the other, William B. Rogers.[43] After his arrival in the United States in 1846, the Swiss zoologist Agassiz exerted such a powerful influence upon the scholars there that Charles Darwin stated in 1854 that he seldom saw "a zoological paper from North America, without observing the impress of Agassiz's doctrines."[44] A large audience attended his popular lectures which, according to the statement by the Boston Society in 1847, "excited the curiosity and called forth admiration of the public, have more than realized the most sanguine expectations of this Society."[45] Agassiz's unfinished lifework in America, the ten-volume *Contributions to the Natural History of the United States*, had more than twenty-five hundred subscribers, which included as many as 752 from Massachusetts.[46] No wonder that "the popular image of natural history in New England was synonymous with Agassiz's name."[47] The major secret of his popularity in turn lay in the carefully and boldly formulated special creationism supported by his impressive knowledge of natural history. As early as 1833, in *Recherches sur les Poissons Fossiles*, Agassiz asserted that the species "do not pass gradually from one to the other, but appear and disappear suddenly without direct relations with their predecessors."[48] All of his works published thereafter invariably maintained this basic doctrine of catastrophism,[49] "essentially a device to preserve the leading tenets of Christian theology and at the same time to give these doctrines a scientific cast."[50] Given Rogers' critical examination of natural history from the point of view of natural philosophy in 1855, his challenge against Agassiz's position was almost unavoidable.

The advent of Darwin's *Origin of Species* in America toward the end of 1859 caused a series of debates between Agassiz and Rogers on the validity of Darwin's thesis. A few skirmishes in the Boston Society and the American Academy of Arts and Sciences in November 1859 and January 1860 prepared the way for a full-scale debate. The Boston Society's meetings in February, March and April, 1860, turned into an arena of confrontation between the two scientists. The dispute began on February 15 when Agassiz discredited Darwin's theory in the presence of Rogers by pointing to the observed fact of equal diversity of animal representatives throughout every geological period. Although Rogers admitted Agassiz's point as a formidable objection to Darwin's thesis, he argued that Darwin would meet such an objection "by the fact that vital characters of some animals fit them for resisting change and extinction better than some plastic natures." Again, defending Darwin, Rogers explained observed interruptions of species in terms of empirically testable facts of emigration and remigration, instead of having recourse, like Agassiz, to a supernal cause of Divine intervention.[51] Given his stronger background in Natural Philosophy, supplemented by his long experience in geological survey, Rogers' advantage over

Agassiz was rather obvious.[52] Thus, in the course of successive confrontations, Agassiz's argumentation gradually dissolved to produce contradictory statements, which even surprised the opponent.[53] The debate, as well as Agassiz's defeat, reflected the shift of power in scientific studies from natural history to natural philosophy, for which Henry, Bache, and Rogers himself were partly responsible. Nevertheless, Agassiz's public influence remained potent, a case which applied equally to his power in Harvard in the early 1860s.

V

Young Charles W. Eliot, at nineteen, graduated from Harvard in 1853, when William B. Rogers, at the age of forty-nine, resigned from the University of Virginia to settle in Boston. In the following year, Eliot entered his nine-year-service at Harvard, first as Tutor in Mathematics and then as Assistant Professor of Chemistry. Immediately before he assumed the tutorship, Eliot sent a letter to his mother dated March 16, 1854, in which he expressed his faith in a scientific career :

> Natural studies, I mean scientific studies, have always been particularly attractive to me ; they excite and stimulate me ; when I hear other men talking of their plans, studies and successes, I always feel a strong desire "to go and do likewise"... The scientific men of America will make their mark on the page of history within the next fifty years, and the young man who starts now with a determination to be a good teacher and a thorough scholar stands a more than fair chance of becoming distinguished.[54]

In the course of his early teaching career, Eliot naturally became skeptical of contemporary studies in the College which tended to waste "four precious years of the lives of such (scientically oriented) boys." [55] His Mathematics course offered a chance to introduce innovations. Applying Trigonometry to Surveying, in a manner reminiscent of Bache's example in his 1851 address, Eliot formed "several sections, to each of which was assigned a portion of the City of Cambridge for survey." Indeed, his class surveyed a large part of the City, "the labor, which was entirely voluntary, being shared by about forty members..." [56]

During the same period, in Boston, William B. Rogers had been actively engaged in physics studies before his committment to the foundation of the Institute of Technology around 1860. Rogers communicated the fruits of his research in the meetings of the American Academy of Arts and Sciences and of the Boston Society, which Eliot often attended. Among others, *The American Journal of Science* published in 1855 a series of long papers by Rogers in optics, collectively entitled as "Observations on Binocular Vision", [57] a topic closely related to theoretical aspects surveying. Given Rogers' general influence over college scientists in New England, including those in Harvard, [58] he might have meant more than a famous physicist for Eliot, in his struggle for the improvement of science training. Indeed, in the words of Eliot's biographer, Rogers' ideas about scientific education "were already matured and doubtless helped to shape Eliot's." [59]

As could be anticipated, toward the end of his early career at Harvard, Eliot became involved in the reform of its Scientific School. As the young head of the chemical laboratory, Eliot joined in 1862 a three-man-committee, made up of Louis Agassiz, Henry

Eustis, and himself, for the preparation of the School's reform plans. By December 1862, in collaboration with Asa Gray, the botanist and a staunch supporter of Darwin, Eliot drafted and presented to the newly-installed president, Thomas Hill, concrete plans for reorganization wih a view to a systematization of general and specialized training programs in the Scientific School. Immediately thereafter, Louis Agassiz proposed a plan for the better organization, which Benjamin Peirce, Professor of Mathematics, supported whole-heartedly. Thereupon, Thomas Hill substantiated Agassiz's ideas into the University Lectures at the neglect of the efforts by Eliot and Gray.[60]

This outcome was expected. A few years before, Asa Gray turned himself into the first American scientist openly to challenge Agassiz's special creationism, followed by Rogers' confrontation with Agassiz, a series of incidents which separated Eliot and Agassiz. Eliot maintained strong sympathy with Asa Gray, which he expressed years later in his tribute to Gray, praising his work as "the largest and most durable contribution to American botanical science."[61] Eliot's description of the person of Benjamin Peirce, Agassiz's confidant, marked a stark contrast. Here Eliot's account, made some seventy years after his experience with the mathematician, vividly described Peirce as possibily the worst teacher Harvard had produced. Hardly addressing his scanty talk to "the students who sat below trying to take notes of what he said," Peirce did not invite them to ask questions, and, in the more advanced class, when he did not like "the form of the student's question,... he would not answer it at all."[62] The student Eliot once revealed his real dissatisfaction with Peirce when he mentioned directly to the mathematician that what

Peirce "had just been saying to us about functions and infinitesimal variables seemed to me to be theories or imaginations rather than facts or realities." Peirce harshly reprimanded Eliot and warned that, unless Eliot was on his guard against his skeptical turn of mind, that tendency would hurt his career.[63] The episode well testified to the nature of subsequent antagonism between Peirce and Eliot. Under the influence of the new physical sciences, Eliot became increasingly interested in chemistry and applied sciences. In contrast, Benjamin Peirce kept considerable distance from this new trend, and even asserted in 1854 on the supremacy of abstract mathematical principles, referring to "the central position of Geometry among the sciences."[64]

The reform efforts had the effect of somewhat isolating Asa Gray in the Scientific School. Yet, an even harder trial awaited Eliot who, when compared with Gray, was much less established as a scientist. When the Rumford Professorship in the School was vacated in 1863, Eliot "naturally aspired" to the position.[65] Louis Agassiz and Benjamin Peirce, however, discouraged Eliot by inviting Wolcott Gibbs of the Free Academy of New York.[66] Thus Eliot lost, in the summer of 1863, "all connection with Harvard University."[67]

Harvard's choice of Gibbs, at the neglect of Eliot, partly derived from the former's study experience in Berlin and Giessen as well as some publications in chemistry, neither of which it found in Eliot. At the same time, however, the zeal for reform, so characteristic of Eliot, was eminently deficient in Gibbs as an able chemist, whom a student remembered as "a reformer who never preached reform."[68] Thomas Hill's thought, however, offers a different clue for Eliot's defeat in 1863. Prior to his appointment as president in 1862, Hill twice expounded at the University his ideas on the hierarchical structure of knowledge. On these occasions, Hill specifically discussed the place of "Natural History", in which he included chemical and mechanical sciences, within the whole range of knowledge : Theology, Psychology, History, Natural History, and Mathematics.[69] Hill regarded Mathematics as a prerequisite to the the study of "Natural History", and "Natural History" as that of History, and so on. The gradual mastery of the four preceding levels of knowledge enabled the appreciation of Theology as the highest, which, in turn, made the understanding of the four levels complete. By thus hierachically arranging five levels of human knowledge, Hill thought he could prevent the invasion of "Natural History" into the other domains, particularly that of Thelogy. This whole scheme by Hill was congruent with Agassiz's natural history, and it was incompatible with Rogers' world views. While Hill settled the disturbances in knowledge derived from the rise of "Natural History" by separating the five levels of knowledge, Rogers solved the same difficulty by connecting different stages of knowledge, heretofore regarded as distinct, from that on the crudest materials in Nature to that on the highest form of human life.[70] Little wonder that Hill complied with Agassiz's group and was reluctant to keep Eliot.

If Eliot's departure from Harvard was thus partly due to Rogers' influence upon Eliot and the consequential discord of the latter with Agassiz's group, the prompt appointment of Eliot by the newly opened Institute of Technology as Professor of Analytical Chemistry in 1865 is easy to understand. In the appointment, Rogers acquired a young chemist who, growing up under his influence, fully demonstrated interests in the teaching and administration of scientific subjects on a new outlook. For Eliot himself, the participation in the Institute's foundation signified a shift from the center of ideology-bound science, dominated by Peirce and Agassiz, to a center of practical, physical sciences, where Eliot could feel, at least temporarily, at home.

Eliot's "The New Education : Its Organization" in the February 1869 issue of the *Atlantic Monthiy* should be interpreted within the context of this enduring opposition in their views on scientific and technical education between Rogers' Institute of Technology and Hill's Harvard, for the article recommended that the training in the latter had to be reorganized along the lines being practiced in the former. Eliot classified the existing institutions for "the new education" into three types : "the scientific 'schools' connected with colleges ; the scientific 'courses' organized within colleges ; and the independent 'schools' especially devoted to non-classical education." [71] The Sheffield Scientific School at Yale and the Lawrence Scientific School at Harvard were of the first type, of which Eliot found the Sheffield School offering a more systematic and cumulative training in the sciences to students selected by a comprehensive admission examination. In these respects, the Lawrence School was eminently deficient, where students were virtually private pupils of professors :

> This system, or rather, lack of system, might do for really advanced students in science, or men in years and acquired habits of study, ··· in fact, the school has been of great service to a score or two of such men, ··· but it is singul-

> arly ill-adapted to the wants of the average American boy of eighteen. The range of study is inconceivably narrow ; and it is quite possible for a young man to become a Bachelor of Science without a sound knowledge of any language, not even his own, and without any knowledge at all of philosophy, history, political science, or of any natural or physical science, except the single one to which he had devoted two or three years at the most.[72]

The School needed a well-balanced and co-ordinated science program, supplemented by general education, and thus its reorganization was inevitable. Nor did Eliot highly evaluate the second type, the scientific courses offered in parallel with classical ones, two irreconciliable entities. The efforts in this direction represented "good temporary expedients during a transition period."[73]

As might be expected, to the third type of institutions which included the Institute of Technology, Eliot gave his strong endorsement. Independent institutions without Latin or Greek requirements, they received boys older than sixteen. Though the Rensselaer Polytechnic Institute in Troy had a longer history, in many respects, the new Institute in Boston overshadowed other similar ones. In Eliot's judgement, the most ample course of instruction for a liberal and practical education as well as training specially adapted to make students ultimately good engineers, manufacturers, architects and so on was "that organized by the Massachusetts Institute of Technology at Boston."[74] Eliot explained in detail the fully prescribed curriculum for the first two years, in addition to the partially prescribed course for the second two years, in the new Institute. The well-developed programs in modern foreign languages and in artistic and humanistic subjects reinforced practical training in the sciences in view of resolving the traditional antithesis between utilitarian and humanistic studies. "Henceforth," concluded Eliot, "the American parent, who wants to give a practical education to his son, may know clearly what is accessible to him as an alternative to the College." [75] Wolcott Gibbs, whose Scientific School at Harvard was thus severely criticized, retorted a few months later, saying that Eliot's article appeared "to have been written in the interest of the Massachusetts Institute of Technology." [76]

How did Eliot, who vouched for the systematic, largely prescribed courses at the Institute and who seemed "surprisingly unconcerned about the elective principle," [77] metamorphose himself into an ardent advocate of the principle in only a short period of time ? Did he promptly withdraw the contention developed in the *Atlantic Monthly* article ? No, he did not. On the contrary, there was a positive consistency between his praise of the Institute system and his advocacy of the elective principle at Harvard. Indeed, in the course of his reform efforts at his Alma Mater, Eliot realized the significance of the Institute of Technology itself for Harvard, which was reflected in his series of unsuccessful attempts to consolidate the two institutions.[78]

How could Eliot commend and even seek to absorb the Institute of Technology with its largely prescribed curriculum without contradicting his advocacy of the free elective principle at Harvard ? The query requires an alternative to the traditional interpretation which explains Eliot's elective principle primarily in terms of his liberalism.[79] In order to elucidate some salient features of his idea, Eliot's inaugural address in 1869 will have to be analyzed in the insight so far gained in the present essay.

On October 19, 1869, Eliot discussed the elective system as one of the key, but certainly not the novel, policies of his administration. For Eliot himself was fully aware that the system in fact had been "gradually developed in this College during the past forty years." Again, by the time of his appointment, the range of elective studies was already "large." [80] Thus, in history as well as in extensiveness of application, the elective principle had rooted deeply at the University. Then, concerning the system, was there any further improvement necessary at Harvard ? According to Eliot, the defect of the current system lay not in the liberty of choice of subject, but in the boundary itself within which the student could make free choice, the boundary of studies which were invariably "liberal and disciplinary." Since the student could not select "between liberal studies and professional or utilitarian studies," in spite of the widely adopted elective principle, the education at Harvard was "nothing less than four years devoted to liberal culture." [81]

As an alternative to this "liberal culture", Eliot proposed training for the professional man who possessed, along with a general knowledge, "a minute and thorough knowledge of one subject which each may select as his principal occupation in life." [82] The needed respect of the tendency of the individual partly stemmed from social purpose and utility. These two objects had to be reconciled. "For the individual," held Eliot, "concentration, and the highest development of his own peculiar faculty is the only prudence. But for the State, it is variety, not uniformity, of intellectual product, which is needful." [83]

In his elective system at Harvard, Eliot thus tried to realize simultaneously liberalism in studies and their social utility. The conscious integration of the two elements in the college curriculum defined the novelty of Eliot's reform, since the two had been regarded as distinct and incompatible. During his early career at Harvard and at the Institute of Technology, Eliot personally experienced the range of application open to scientific studies. Moreover, he learned that, when carried on under a certain plan, technical education could be liberalized, a point which William B. Rogers had consistently expounded in the different versions of the Institute plan, and which Eliot himself elaborated in the *Atlantic Monthly* article.[84] The liberal culture had been expected to carry its students "beyond the narrow bounds of what is merely local and temporary, and plant their feet in the vast open field of comprehensive wisdom, and on the solid basis of immutable truth."[85] In contrast, culture now increasingly bore vocational and this-worldly aspects, and, as a result, in the words of Rogers' friend, he would "come hereafter to be considered to have the best liberal education, who, having discovered betimes what he was best fitted to do in life, shall have prepared himself in the soundest and most perfect manner to do that work in the broadest and most liberal spirit."[86]

Whether one college president or other of this period was *generally* disposed to the elective principle or not, did not count much. The more important thing was *where* he insisted on the introduction of that principle. Eliot strongly advocated the elective system at Harvard, which needed a reform of studies on the new idea of culture and profession. Had he remained in the Institute of Technology, however, he would have done things differently. The proposition of the free choice of studies itself was by no means unique. Concerning Harvard, even Rogers asserted in 1846 that it was far better "to make all the studies *free*."[87] In fact, the emergence of the new methods and habits of scientific inquiries and their implications for liberal and professional education stimulated the reorganization of colleges and universities. In this sense, the prescribed curriculum in the Institute of Technology was not unrelated with the movement of elective system in Harvard under Eliot. On the contrary, the former might have been one of the strongest incentives for the latter to introduce that system.

The rise of the elective principle should be interpreted within the context of the gradual replacement of the older ideas of science and culture by the new physical sciences and the ideas of culture based thereon. The latter's distinction consisted in their capacity massively to transform our living environment through their application to production and transportation. When the colleges and universities represented by Harvard exposed themselves to this transformation in the sciences and culture, partly initiated by the Institute of Technology, they adopted the elective principle as one of the most reasonable measures of reform. If Charles W. Eliot of Harvard was a great interpreter of this reform movement, William B. Rogers of the Institute of Technology, along with a few other scientists, was a great originator of that same movement.

Footnotes :

1) As for the history of the rise of the elective principle in 19th century America, see ; R. Freeman Butts, *The College Charts Its Course*. New York, 1939 ; Richard Hofstadter and C. DeWitt Hardy, *The Development and Scope of Higher Education in the United States*. New York, 1952, Chapter II ; Frederick Rudolph, *The American College and University*. New York, 1965, Chapter 14 ; do., *Curriculum : A History of the American Undergraduate Course of Study Since 1636*. San Francisco, 1977, Chapters 5 and 6.
2) A few examples are : Stanley Guralnick, *Science and the Ante-Bellum American College*. Philadelphia, 1975 ; Margaret Rossiter, *The Emergence of Agricultural Sciences : Justus Liebig and the Americans, 1840—1880*. New Haven, 1975 ; Theodore Bozeman, *Protestants in an Age of Science*. Chapel Hill, 1977.
3) For James Smithson's life and works, see : William J. Rhees, *James Smithson and His Bequest*. Washington, 1881, pp. 1—23.
4) See : William Howard Taft, "The Smithsonian Institution··· Parent of American Science." In *Conference on the Future of the Smithsonian Institution*. Washinton, 1927, p. 11 ; William J. Rhees ed., *The Smithsonian Institution : Documents Relative to Its Origin and History*. Washington, 1880 pp. 837—929.
5) See : *Ibid.*, p. 473 ; (Asa Gray), "The Smithsonian Institution." *The American Journal of Science and Arts*, XX, 58 (July 1855), p. 5.
6) See : William J. Rhees ed., *The Smithsonian Institution : Journals of the Board of Regents, Reports of Committees, Statistics, Etc.* Washington, 1879, pp. 25—26.
7) See : *Ibid.*, pp. 73, 112—115.
8) *Debate in the Senate of the United States, January 18, 1855, on the Letter of Hon. Rufus Choate, concerning the Management of the Smithsonian Institution*. Washington, 1855, p. 3.
9) Rhees ed., *The Smithsonian... Documents...* p. 594.
10) Joseph Henry. *Scientific Writings*. Washington, 1886, I, p.264.
11) *Ibid.*, p. 272.
12) "Organization of the Smithsonian Institution." The American Asso-

ciation for the Advacement of Science. *Proceedings*,1849, p. 84.
13) Henry, *op. cit.*, p. 277.
14) Rhees ed., *The Smithsonian... Journals...* p. 106.
15) *Ibid.*
16) See : *Ibid.*, p. 108.
17) Henry, *op. cit.*, p. 49.
18) *Ibid.*, p. 328.
19) Joseph Henry, "Memoir of Alexander Dallas Bache, 1806—1867." National Academy of Sciences. *Biographical Memoirs*, I, Washington, 1877, p. 186.
20) "Address of Professor A. D. Bache...on Retiring from the Duties of President." The American Association for the Advancement of Science, *Proceedings*, 1852, p. xliii.
21) *Ibid.*, p. xlv.
22) A. D. Bache, "The Annual Address, Being a Paper upon the Gulf Stream, January 27, 1856." *Bulletin of the American Geographical and Statistical Society*, II, p. 106.
23) "Address of Professor A. D. Bache..." p. xlv.
24) See : A. Hunter Dupree, *Science in the Federal Government*. Cambridge, 1957, p. 118.
25) "Address of Professor A. D. Bache..." p. xlvii.
26) Ralph S. Bates, *Scientific Societies in the United States*. Cambridge, 1965, p. 30.
27) See : F. R. Moulton, "The Association··· Past, Present and Future." *The Scientific Monthly*, XLVIII, 1939, pp. 285—286 ; Sally Gregory Kohlstedt, *The Formation of the American Scientific Community*. Urbana, 1976.
28) See : Emma Rogrs ed., *Life and Letters of William Barton Rogers*. I, Boston, 1896, pp. 15—16 and 54.
29) *Ibid.*, p. 26.
30) See : George H. Daniels ed. *Nineteenth Century American Science*. Evanston, 1972, p. 218.
31) See : William B. Rogers, *Elements of Mechanical Philosophy*. Boston, 1852, Chapters VIII through XIV.
32) See : *Reports of the First, Second, and Third Meetings of the Association of American Geologists and Naturalists*. Boston, 1843, pp. 474—531.

33) See : Charles Gillispie, *Genesis and Geology*. Cambridge, 1951.

34) Rogers, *op. cit.*, pp. 1—2.

35) Joseph Henry, "Syllabus of a Course of Lectures on Physics." The Board of Regents of the Smithsonian Institution, *Anual Report*, Washington, 1857, pp. 187—188.

36) Rogers, *op. cti.*, p. 3.

37) See : *Ibid.*, pp. 4—6 ; Shigeru Nakayama. *Rekishi to shiteno Gakumon*. Tokyo, 1974, pp. 195—196.

38) William B. Rogers, *Address before the Lyceum of Natural History of Williams College, August, 14, 1855*. Boston, 1855, pp. 4—9.

39) *Ibid.*, p. 26.

40) *Ibid.*, p. 29.

41) See : Gillispie, *op. cit.*, pp. 99—102 ; Loren Eiseley, *Darwin's Century*. New York, 1961, p. 67.

42) See : Akira Tachikawa, The Two Sciences and Religion in Ante-Bellum New England. Ph. D. diss., Univ. of Wisconsin, 1978, Chapters, III and VI.

43) See : John C. Warren, *Address to the Boston Society of Natural History*. Boston, 1853, pp. 11—12.

44) Quoted in : Edward Lurie, *Louis Agassiz : A Life in Science*. Chicago, 1960, p. 266.

45) Thomas Bouve, *Historical Sketch of the Boston Society of Natural History*. Boston, 1880, p. 45.

46) See :Louis Agassiz, *Contributions to the Natural History of the United States*. I, Boston, 1857, pp. xvii ff.

47) Lurie, *op. cit.*, p. 275.

48) Quoted in : Arnold Guyot, "Memoir of Louis Agassiz, 1807—1872." National Academy of Sciences. *Biographical Memoirs*, II. Wasington, 1886, p. 58.

49) See : Louis Agassiz, *An Introduction to the Study of Natural History*. New York, 1847, p. 58 ; do., *The Structure of Animal Life*. New York, 1865, pp. 83—84 and 91 ; do., *Methods of Study in Natural History*. Boston, 1868, p. 147.

50) Eiseley, *op. cit.*, p. 67.

51) See : The Boston Society of Natural History. *Proceedings*, VII, 1861,

pp. 231—234.

52) See : William M. Smallwood, "The Agassiz-Rogers Debate on Evolution." *The Quarterly Review of Biology*, XVI, 1, 1941, pp. 7—8 ; Jules Marcou, *Life, Letters, and Works of Louis Agassiz*. II, New York, 1896, pp. 106—109.

53) See : The Boston Society of Natural History, *Proceedings*, VII, p. 274.

54) Quoted in : Henry James, *Charles W. Eliot : President of Harvard University, 1869—1909*. Boston, 1930, pp. 63 and 65.

55) Quoted in : *Ibid.*, p. 94.

56) Charles W. Eliot, "President Eliot's Own Story." *The Harvard Graduates' Magazine*, XXXV, 1962, p. 226.

57) See: *The American Journal of Science*, Second Series, XX pnd XXI.

58) See : Francis A. Walker, "Memoir of William Barton Rogers, 1804—1882." National Academy of Sciences, *Biographical Memoirs*, Washington, 1895, pp. 9—10 ; Nathaniel S. Shaler, *Autobiography*. Boston, 1909, pp. 104—105.

59) James, *op. cit.*, p. 96n.

60) See : Hugh Hawkins, *Between Harvard and America*. New York, 1972, pp. 23—24 ; William G. Land, *Thomas Hill : Twentieth President of Harvard*. Cambridge, 1933, p. 139.

61) Charles W. Eliot, "A Happy Life : A Tribute to Asa Gray." *American Contribution to Civilization*. New York, 1890, p. 279.

62) Charles W. Eliot, "Reminiscence of Peirce. "*The American Mathematical Monthly*, XXXII, 1925, p. 2.

63) See : *Ibid.*

64) Benjamin Peirce, "Address..," The American Association for the Advancement of Science, *Proceedings*, Cambridge, 1955, p. 8.

65) Eliot, "President Eliot's Own Story." p.231.

66) See : James, *op. cit.*, p. 107.

67) Eliot., *op. cit.*, p. 231.

68) F. W. Clarke, "Biographical Memoir of Wolcott Gibbs, 1822—1908." National Academy of Sciences, *Biographical Memoirs*, VII, Washington, 1913, p. 10.

69) See : Thomas Hill, *The Annual Address before the Harvard Natural History Society*. Cambridge, 1853, pp. 6—17 ; do., *Liberal Education, An Address Delivered before the Phi Beta Kappa Society*. Cambridge, 1858,

pp. 6—7.

70) See : Rogers, *Address before the Lyceum*... pp. 13—20.

71) Charles W. Eliot, "The New Education : Its Organization." *The Atlantic Monthly*, February, 1869, p. 205.

72) *Ibid.*, p. 210.

73) *Ibid.*, p. 215.

74) *Ibid.*, p. 217.

75) *Ibid.*, p. 219.

76) Wolcot Gibbs, "Note." *The Atlantic Monthly*, April, 1869, p. 514.

77) Hawkins. *op. cit.*, p. 43.

78) See : Emma Rogers ed. *op. cit.*, II, p. 293 ; Samuel C. Prescott, *When M. I. T. was "Boston Tech" : 1861—1916*. Cambridge, 1954, pp. 74—78.

79) See : Hawkins, *op. cit.*, pp. 74, 94 and passim ; footnote 1 of this essay.

80) Charles W. Eliot, "Inaugural Address as President of Harvard College." *Educational Reform*. New York, 1898, p. 13 ; see also : do., *Harvard Memories*. Cambridge, 1923, pp. 16ff.

81) Eliot, Inaugural Address..." p. 14.

82) *Ibid.*, p. 4.

83) *Ibid.*, p. 13.

84) See : William B. Rogers, A Plan for a Polytechnic School in Boston, 1846. In Prescott. *op. cit.*, pp. 331—336 ; do., *Objects and Plan of an Institute of Technology*. Boston, 1860.

85) W. S. Tyler, *Prayer for Colleges, A Premium Essay*. New York, 1850, p. 63.

86) William P. Atkinson, *On the Right Use of Books : A Lecture*. Boston, 1879, pp. 57—58.

87) Emma Rogers ed. *op. cit.*, I, p. 268.