HISTORIA MATHEMATICA 1 (1974), 151-166

THE BEGINNINGS OF MATHEMATICS IN A HOWLING WILDERNESS

BY EDWARD R. HOGAN
WILSON COLLEGE, CHAMBERSBURG, PENNSYLVANIA

SUMMARIES

This paper analyzes factors that influenced the development of mathematics in Anglo-America, particularly New England, before the Revolutionary War. It discusses the effects on the emerging nation of the development of mathematics in Europe.

Cette étude analyse les causes qui influençaient le devéloppement des mathématiques en Amérique anglaise, et surtout en Nouvelle-Angleterre, avant la révolution américaine. L'auteur discute l'action sur la nation surgissante de l'évolution des mathématiques en Europe.

By the Revolutionary War America had produced such notable political leaders as Washington, Jefferson and Franklin. As early as the middle of the nineteenth century Thoreau, Emerson, Hawthorne, Cooper, Melville and others had cast considerable doubt on Tocqueville's pronouncement that a democratic society would be incapable of great literary accomplishment. And by the Civil War Whitney, Howe, McCormick and a host of others had contributed to a growing technology in the United States that would soon surpass that of Europe. In the ten years from 1850 to 1860 more patents were granted by the United States that by England and France combined. [Carman 1960, 490]

But despite impressive achievements in many areas, America did not begin to make any real contributions in mathematics until near the end of the nineteenth century, when Benjamin Peirce and J. Willard Gibbs emerged as native scholars, and the country was willing to support the imported efforts of J. J. Sylvester. Hence, all facets of American culture did not develop concurrently. Despite an early contribution to political leader-ship, the arts, technology and many of the sciences evolved at a slower pace, and mathematics evolved even more slowly. The rate of development of various segments of American culture reflected the influences that acted upon the society and the needs and goals of the emerging nation. This paper attempts to analyze the factors that influenced the development of mathematics in Anglo-America before the Revolutionary War and to discuss the effects that mathematical achievements in Europe had on the emerging American nation.

The development of modern mathematics in Europe was, of course, part of the Renaissance. In a very general sense the growth of mathematics in the Anglo-American colonies may be regarded as part of this revival of western culture. Although the Italian Renaissance was well under way by Columbus' time, in England, and in other European countries, the end of the medieval period came much later. [Jones 1952; Ball 1889, 12-13] Medieval society was invariably transferred to the colonies, and in many instances medieval characteristics persisted in the colonies long after they had disappeared in the parent European nations. The effect of this situation on mathematics in the British American colonies was obviously one of strong retardation. Even after England's outstanding contributions to mathematics in the seventeenth century, the isolation of the colonies made contact with British mathematics difficult. An additional retarding influence, especially to those colonies with close intellectual ties to Great Britain, was the subsequent stagnation of British science during the eighteenth century.

A related reason for the late development of mathematics in the United States was the comparatively early professionalization of mathematics in Europe which caused a late professionalization in the United States. [Daniels 1967] Most of the outstanding seventeenth-century mathematicians were amateurs -- e.g., Fermat, Descartes, Pascal and Leibniz. They were neither associated with a university or academy, nor did they depend upon mathematics for their livelihood. They pursued mathematics as an avocation. Other seventeenth-century mathematicians, including Newton, were professionals. The work done by all of these men, especially that of Newton, advanced mathematics to the stage where it was very difficult for a person to contribute significantly to the development of mathematics without giving it his full-time effort. Consequently we find the majority of eighteenth-century mathematicians receiving support from a university or, perhaps more typically, an academy. Maclaurin, and Jakob and Johann Bernoulli were associated with universities. Laplace was a professor at the military school of Paris. Euler, Lagrange and D'Alembert were supported by academies. Hence, by the eighteenth century it was becoming increasingly necessary for a person to have full-time financial support in order to be a mathematician. But American society was not willing to give this support until the end of the nineteenth century. Colonial America also lacked a class sufficiently rich to patronize the arts and sciences, as the nobility did in Europe. Again, it was not until the end of the nineteenth century, when the super-rich emerged in the United States, that foundation money was available in any quantities to support the sciences in America.

But this view of professionalization begs the question: why wasn't the United States able or willing to support a mathematician until near the end of the nineteenth century? Americans had already produced great literature, showed an inventive genius and supported work in the natural sciences before any passable mathematics was done. The most obvious retarding influence was, of course, the wilderness itself. One would hardly wish to come to a new and hostile environment to be a mathematician. However, the New World was conducive to the study of some of the sciences. It was especially conducive to the sciences that had descriptive phases, such as astronomy and botany, that profited from the New World by either its geographic position, as was the case with astronomy, or a wealth of new specimens, as was the case with botany. But any science that was substantially observational, or had substantially observational aspects, gave the Americans an opportunity to make a contribution even if they were unable to improve upon basic theory. Mathematics, lacking this quality, was particularly inaccessible to the colonial. The following scientific work of John Winthrop, Jr. exemplifies this situation.

In 1663 Winthrop brought a three-and-one-half foot telescope to the colonies. His geographic advantage enabled him to make several observations of comets which he sent to the Royal Society. But in 1664 Winthrop missed an opportunity to observe the transit of Mercury because he lacked sufficient scientific ability to predict the occurrence. He had to depend upon instructions from the Royal Society, which came too late to make the observations. [Daniels 1971, 61] Even the electrical work of Franklin, the first American scientist to be widely recognized in Europe, was possible only because the theory of electricity had not become mathematical. It was still possible to carry on important electrical experiments using crude equipment, and there was no substantial electrical theory with which one needed to be familiar. [Daniels 1971, 66]

Despite the limitations of the wilderness, Newton and his discoveries stimulated a great deal of popular interest in mathematics among educated and professional men in the colonies. But these men remained largely amateurs, and none of them, amateur or professional, produced significant mathematical research. Voltaire's comments were applicable to the educated colonial:

> *... a small number pursue those [works] of Sir Isaac because to do this the student must be deeply skilled in the mathematics, otherwise those works will be unintelligible to him. But not withstanding this these great men [Descartes and Newton] are the subjects of everyone's discourse.* [Voltaire 1910, 113]

Excluding slaves and indentured servants, men who came to

Anglo-America did so for two principal reasons: to make a fortune or to avoid religious persectuion. Concerning those who sought wealth, Dewitt Clinton stated in an address to the Literary and Philosophical Society of New York in 1814:

> *Ancient migrations were generally the offspring of want.... A different principle seems to have led to the first colonization of America. The discovery of this western world appears to have infused a new spirit into Europe: the imaginations of men were dazzled with fablulous stories of dorados, or mountains of gold, and of fountains by which the human race flourished in immortal youth. In this land the god of wealth was supposed to have erected his temples, and his votaries flocked from all quarters to propitiate his blessings. When experience had sobered the distempered fancies of these adventurers, and had convinced them of their delusion, they still discovered that, although the precious metals were not within their grasp, yet that their cupidity could be amply gratified by the abundant products of the soil. The settlement of this country was thus made with a view to the acquisition of wealth; knowledge was out of the question. The attachments of the emigrants, like their origin, were exotic; the land of their adoption was considered as secondary and inferior, in every respect, to the land of their nativity; and their anxious eyes were constantly directed to the period when they could return to their native soil laden with the bounties of the new world.* [Clinton 1815, 4-5]

Those who came to acquire wealth, whether through gold, furs, or tobacco, had very little need for mathematics. They did need some knowledge of a calendar and very often had an interest in astrology. Their needs gave rise to the study of astronomy and sufficient mathematics to make necessary calculations. The association of mathematics and astronomy persisted until near the end of the nineteenth century.

In addition to simple avarice, there was a predominant feeling among the colonists that usefulness and functionalism were moral imperatives. One of the chief tenets of the Enlightenment was the utilitarian value of science. Cotton Mather's *Christian Philosopher*, the first work published by an American that gave a general Newtonian approach to the physical sciences, exhibited this viewpoint. George Daniels notes:

> *One of the most striking characteristics of the work was an attitude that could only be termed extreme -- perhaps even "excessive" -- functionalism. Mather seemed positively driven to find a reasonable use for everything.* [Daniels 1971, 82]

Franklin too held these typical utilitarian values. He wrote, "What signifies philosophy that does not apply to some use?" [Hindle 1956, 192] And he felt unable to justify the time he had spent upon the construction of magic squares, which he felt were useless. [Hindle 1956, 192] As Franklin's feelings indicate, this colonial attitude undoubtedly had some negative influence upon the study of "pure" mathematics for which there was no apparent application. But as navigation and surveying were both clearly useful and mathematical, the association of mathematics with these useful pursuits may have justified, to the colonial society, some study of mathematics beyond that of obvious utilitarian value. When the American Philosophical Society endeavored to raise money to purchase the necessary apparatus to observe the transit of Venus expected in 1769, they appealed, somewhat fallaciously, to the practical aspects of the venture. They declared that the observations were "an object, on which the Promotion of Astronomy and Navigation, and consequently of Trade and Commerce so much depends." [Hindle 1956, 135] Actually the observations were beneficial to astronomy, but not to navigation or commerce. In benefiting and stimulating an interest in astronomy the venture may even have stimulated the study of mathematics.

Surveying, navigation and almanac-publishing were important to commerce and stimulated the development of mathematics in the colonies. The Southern planters eventually needed to survey their lands; as early as 1585 Sir Walter Raleigh had Thomas Harriot survey and map a portion of what is now North Carolina. Among those who made important surveys in colonial America were Rittenhouse, Holland, Romans, Mason and Dixon. [Smith and Ginsburg 1934, 42-96; Hindle 1956, 31-32] The fundamentals of surveying were fairly widely known throughout the colonies. Thomas Jefferson had surveying instruments and a knowledge of surveying. Among the well-known Americans who served as surveyors were George Washington and George Rogers Clark. [Smith and Ginsburg 1934, 42] Indeed, with the exception of simple computation and an understanding of the calendar, surveying and map-making were the most common applications of mathematics in the colonies.

Even the more primitive methods of navigation required some knowledge of mathematics. In his popular seventeenth-century work *Practical Navigation*, John Seller stated that to master the nautical science "four things are subordinate Requisites. Viz: Arithmetic. Geometry. Trigonometry. The Doctrine of Spheres." [Cotter 1968, 1] Throughout the colonial period, attempts to improve navigation, particularly ways to find longitude, stimulated interest in mathematics. In 1598 Philip II of Spain offered a reward for the invention of a way to find longitude at sea. And in 1674 Sir Jonas Moore and Sir Christopher Wren convinced the English King Charles II to establish an observatory for the benefit of navigation, especially to get good lunar tables.

Mathematics courses taught at Harvard, Yale, and William and Mary stressed applications to navigation and surveying from the beginning of the eighteenth century. [Smith and Ginsburg 1934, 55] In addition many men offered private instruction in mathematics for navigation during this century. [Smith and Ginsburg 1934, 33-34] By the time of the Revolution courses in navigation were offered in most coastal cities, and shortly after the Revolution even small seaport towns had private schools of navigation that operated during the winter. [Hindle 1956, 166; Morison 1961, 144]

Another commercial endeavor that had a positive effect on mathematics in the colonies was the publishing of almanacs. [Jorgenson 1935; Daniels 1971, 72-76] In New England almanacs were found in practically every home and were read almost as frequently as the Bible. These publications were often compiled by men who had mathematical and astronomical interests, and it was common for them to include several pages of technical information about their favorite subjects. In New England almanacs were the principal written agencies for disseminating the scientific advancements of Isaac Newton. [Daniels 1971, 72]

There was little other commercial activity that stimulated the study of mathematics, as most eighteenth-century technology required little mathematics. Hence, the mercantile system, by stimulating navigation, actually encouraged mathematics even though it discouraged native industry. Many people who were introduced to mathematics through surveying or navigation subsequently took a strong interest in apparently unpractical mathematics. Jefferson states in a letter of 1799:

> *I have to acknolege [sic] the reciept of your favor of May 14. in which you mention that you have finished the 6. first books of Euclid, plane trigonometry, surveying and algebra and ask whether I think a further pursuit of that branch of science would be useful to you. there are some propositions in the latter books of Euclid, and some of Archimedes, which are useful, & I have no doubt you have been made acquainted with them. trigonometry, so far as this, is most valuable to every man. there is scarcely a day in which he will not resort to it for some of the purposes of common life; the science of calculation also is indispensible as far as the extraction of the square & cube roots, Algebra as far as the quadratic equation & the use of logarithms are often of value in ordinary cases: but all beyond these is luxury; a delicious luxury indeed; but not to be indulged in by one who is to have a profession to follow for his subsistence. in this light I view the conic sections, curves of the higher orders. perhaps even spherical trigonometry, Algebraical operations beyond the 2d*

> *dimension, and flusions.* [Smith 1932-1933; Smith and Ginsburg 1934, 62-63]

Dirk J. Struik makes the following comment with respect to John Winthrop:

> *John Winthrop's scientific activities show clearly that colonial science was not exclusively utilitarian. Science, seriously undertaken, can never be purely practical, not only because practical questions need theoretical understanding for their solutions, but also because the scientific mind simply does not function in such an exclusively practical way. Once the inquiring mind is thoroughly aroused, it does not stop at the solution of utilitarian questions, but begins to ask for pure knowledge. The reward lies in the discovery of a deeper truth than appears at first, and in eventual control of more powerful forces of nature.* [Struik 1948, 26-27]

The needs and objectives of those who came to America for religious reasons, even though not devoid of commercial interests, were different from those of the adventurer-entrepreneur. In New England the Puritans endeavored to establish a theocracy, a Holy Commonwealth. They were a whole displaced society and a well-educated one. When Harvard College was founded in 1636 the entire population of New England was only about 4000, and Boston was a village of about 30 houses, but approximately 100 men in the colony had attended Oxford or Cambridge, 80 of them having graduated, and an additional 20 men living in the colony were graduates of Scottish universities. [Smith and Ginsburg 1934, 9]

The Puritans not only needed an educated clergy, but considered it necessary for salvation to be able to read the Bible and learn a catechism:

> *After God had carried us safe to* New England, *and we had builded our houses, provided necessaries for our liveli-hood, rear'd convenient places for Gods worship, and setled the Civill Government: one next thing we longed for, and looked after was to advance* Learning *and perpetuate it to Posterity; dreading to leave an illiterate ministry to the Churches when our present ministers shall lie in the Dust.* [Miller and Johnson 1963, 701]

Although mathematics was at first neglected in New England schools, this strong, religiously-motivated support for education eventually had an important positive effect on American mathematics. The emphasis on education in the South was much weaker. The Southern plantations were large and far apart; distances made it impractical for any number of children to meet regularly in a centrally-located school house. The Southern view of education was also more aristocratic. Until the middle of the eighteenth century education in the South consisted largely of tutors and private schools. Of the nine colleges existing before the Revolution only William and Mary was located below the Mason-Dixon line. The Puritans had a broader interest in education than simply providing a clergy for future generations. The reference to "Learning" in the above quotation is reminiscent of Bacon. The 1650 charter of Harvard College makes no mention at all of training the ministry; it states that the purpose of the college was to be "the advancement of all good literature, Arts and Sciences. [Morison 1936, 29]

This atmosphere helped to make Massachusetts the first colony receptive to the Enlightenment and gave Boston early prominence in colonial science. Philadelphia, which later overtook Boston as the scientific capital, was not even in existence when Newton wrote the *Principia*. The Southern colonies lacked the urban centers of population that were necessary for the development of extensive scientific activity.

In examining the development of mathematics as part of the evolution of scientific thought in the colonies, New England is important not only because it was the first intellectual center, but also because New England affords us an exceptionally good opportunity of observing the genesis of a society's scientific thought. The immigration to New England which began in 1620 ceased almost entirely in 1649. At this time the English Revolu tion and execution of Charles I gave freedom of worship to Puritans in England, making it unnecessary to hazard the dangerous journey to the New World. There was no significant new influx of immigrants into New England until the middle of the nineteenth century. George Daniels notes:

> *It was a small, homogeneous society -- numbering no more than one hundred thousand by 1700 -- transplanted to a New World, accessible only with difficulty, and carrying with it the best of current learning. We are able to observe in New England, as nowhere else, the actual processes of intellectual change.* [Daniels 1971, 71]

Initially the Puritans founded a highly religious medieval society. In Perry Miller's words:

> *The orthodox colonies were, as they themselves proudly admitted, "theocracies," which meant that they were medieval states, based upon the fixed will of God, dedicated to the explicit purposes of Revelation, that they were societies of status and subordination, with the ranks of man arranged in a hierarchical series, the lower obedient to the higher, with gentlemen and scholars at the top to rule and direct.* [Miller 1967, 43]

But very quickly, almost immediately, there was a flux in the Puritan's values and ideas. Several things caused this change. One was the growth of scientific thought in England, with which the Puritans always had some contact, and another was the outgrowth of inconsistencies within the Puritans' own social system.

Important to an understanding of the development of their scientific thought is the fact that the Puritans believed in a covenant theology. That is, they believed that the predestined elect entered into a covenant with God, similar to the covenant between Abraham and Jehovah in Genesis. In this covenant the participant was not saved merely by a passive act of grace, as in traditional Calvinism, but by an active contract with God, where one agreed to obey God's will and in return God promised to grant him salvation without exception. There were never more than a fifth of the population whose religious experience qualified them to be one of these "elect" of God and consequently to be admitted to church membership. [Miller 1967, 51] But the Puritans extended the idea of an individual covenant to the concept of a covenant between God and a political body. In this situation, since many in the community were not in a personal covenant with the Lord, their reward could not be postponed until an after life; therefore, God was obliged to provide immediate and temporal rewards for the obedience of his covenant people and conversely punish them when they strayed from his will. In contrast, God was free to act capriciously with the heathen nations and even with other Christian nations.

To the traditional Calvinist the physical universe was under the constant direction of God's will. All events that transpired, a comet, an epidemic of smallpox, a rainstorm, a good harvest, were not the result of natural law alone. Each event was caused by a rational Being, for rational reasons. Hence, when a people entered into a covenant with God, He was obliged to make natural events coincide with the moral behavior of the covenant people. An earthquake would necessarily be a sign from God of the society's erring and thus necessitate a day of fasting and repentance. On the other hand a bountiful harvest would show God's pleasure with his people and call for a day of thanksgiving.

Such was the ideology that the Puritans brought with them to the New World. Their assumption that natural disasters were punishments from God and should be met with public fasting was very successful in the early history of the colony. [Miller 1967, 14-15] Eventually the fasts seemed less fruitful, especially during King Philip's war. But the remedy was more, not less, fasting.

Eventually we see the beginning of a change of attitude in Puritan society:

> *... in the Massachusetts proclamation for October 1652, a subtle modification of the formula was introduced:*

> *a fast was ordered for a number of reasons, most of them conventional -- storms and rains, wars in England, the growth of heresy -- but at the same time, among the provoking occasions for this fast were listed "the worldly mindednes, oppression, & hardhartednes feard to be among us." For the first time, the sins themselves were enumerated as evils from which the society was suffering along with such external afflictions as hitherto had furnished the causes for a ceremony.* [Miller 1967, 21]

This shift in thought of repenting for the sin instead of the punishment or physical affliction marked "the beginning of an alteration that grew perceptibly with the years. Within a decade the formula was completely transformed. [Miller 1967, 21-22] Hence, the society was becoming less superstitious, and increasing its recognition of natural law. In the above case, instead of relating coincidental physical phenomena to moral behavior, the New Englanders were increasingly associating moral problems with their direct causes.

Throughout New England we see an increasing acceptance of natural law. As noted before, Cotton Mather's *Christian Philosopher*, published in 1721, was the first book published by an American that exhibited a strong influence from Newtonian science. It expressed a point of view that would have been acceptable to any Enlightenment philosopher. In this work Mather "made it clear... that... the orthodoxy of New England would hereafter need to be couched in phrases compatible with the *Principia*." [Miller 1967, 33] In the introduction to his work, Mather declared:

> *The Essays now before us will demonstrate, that Philosophy is no Enemy, but a mighty and wondrous Incentive to Religion; and they will exhibit that Philosophical Religion, which will carry with it a most sensible Character, and victorious Evidence of a reasonable Service.* [Mather 1721, 1]

In addition to the growing acceptance of natural law, another modification was taking place in Puritan Society. As noted above the New Englanders endeavored to establish a Holy Commonwealth ruled by a static economic code that was a survival of the Middle Ages. [Miller 1967, 33] However, two forces in the same community were in diametric opposition to this goal. The first was the economic opportunity that the settling of the new land offered for the flux in economic status and position. The second was what is generally referred to as the "protestant ethic." That is, honest labor in the pursuit and the acquisition of wealth were viewed with complete approval. [Miller 1967, 33-36] In addition to these factors, economic opportunity was increased by political events when in 1691 the colonial charter was reinstated after the Glorious Revolution in England. At this time citizenship was given on a basis of property ownership rather than church membership. This event was of considerable significance, since church membership was limited to the "elect" who had demonstrated a substantial commitment to their faith.

As in any society with rapidly changing values, there were conflicting points of view in New England. Some men endeavored to maintain the status quo or were even reactionary; others were eager to disseminate change. We observe this attitude with respect to science. While, as the principal educated class, the clergy were the leaders in introducing modern science to New England, there were many instances where the clergy spoke out against scientific pursuits. In the early seventeenth century science had not yet demonstrated much practical worth, and many Puritans viewed it as a frivolous pastime. Indeed the feeling that science was a wealthy man's hobby persisted in both England and America throughout the colonial period. If too much time were spent on the investigation of science, too little time might be spent on the perfection of one's soul. John Cotton warned in *A Briefe Exposition... upon... Ecclesiastes* that:

> *... the study of these natural things, is not available to the attainment of true happinesse; for how should that which is restlesse..., procure us setled rest and tranquillity, which accompaniteth true happinesse?* [Miller and Johnson 1963, 729]

Such sentiments retarded the teaching of science in general and mathematics in particular. Since mathematics was not essential to salvation it was often neglected or ignored in curricula in New England schools, especially early in the colonial period.

But more often than not the clergy were willing to accept new ideas and incorporate them into their rationale, as has already been pointed out in the case of Cotton Mather. Exemplifying this attitude is the instance of Increase Mather's preaching a sermon describing comets as portents of God's anger. When he was informed by an English acquaintance that his views had been challenged by Dr. Spencer of Cambridge, he sent for a copy of Spencer's book. After he had studied the book he became convinced that comets were due to natural causes and delivered a public sermon where he recanted his old views and expressed his new ones. [Shipton 1935, 140]

Traditionally it was worthwhile for a Puritan to study science if, by doing so, he was better able to see God's order and greatness. The Newtonian physics was very amenable to this point of view. Newton's discovery of universal law established the concept of a natural immutable law that even God Himself could not break, even though he had created it. Although the orthodox Puritan was reluctant to deny God the ability to break natural law, he was pleased to see evidence in nature of God's existence and magnanimity. And the Calvinistic concept of predestination and unworthiness of man is not too far from Voltaire's statement in his *Ignorant Philosopher*:

> *Indeed, it would be very singular, that all nature, that all the planets, should obey eternal laws, and that there should be a little animal, five feet high, who, in defiance of these laws, could act as he pleased, at the mere direction of his own caprice.* [Voltaire 1779, 13]

The Newtonian influence resulted in a gradual shifting of the concept of God as a hurler of thunderbolts to the concept of God as watchmaker, with the subsequent rise of interest in science and mathematics.

The increase in acceptance of scientific thought, primarily through the influence of Newton's *Principia*, of course had a positive effect on mathematics throughout the British colonies. As natural philosophy and mathematics were recognized as important and compatible with religion they were increasingly taught in the universities. Eventually there was a need for full-time faculty members who were solely teachers of mathematics and natural philosophy, and not theologians or clergymen. Although throughout the seventeenth century college mathematical curricula in the colonies contained little more than arithmetic, by the eighteenth century conditions had improved considerably. LeFevre at William and Mary was the first professor of mathematics in the colonies. [Phalen 1946] Unfortunately, he was dismissed for insobriety in 1712, after only one year. The first important professor of mathematics in the colonies was Isaac Greenwood, who was at Harvard from 1728 to 1738; he too was finally dismissed after a persistent record of intoxication. But Greenwood was succeeded by John Winthrop, who held the Hollis chair at Harvard with distinction. By the time of the Revolution, most of the American colleges were teaching at least some substantial mathematics, and often a course was offered that included the study of Newton's fluxions. Many of the colleges now had professorships of mathematics. Even though the men that filled these posts were not productive creative mathematicians, they replaced the clergy as the colonial scientific leaders, and their existence was vital to the genesis of professional science and mathematics in what was to become the United States. [Smith and Ginsburg 1934; Simons 1925]

Economic opportunity and the resulting growth of the mercantile middle class had the positive effect of endowing many men with sufficient wealth to pursue science and mathematics as an avocation. Nathaniel Bowditch is perhaps the most outstanding example of what these circumstances made possible. The growth of the middle class with the consequent increase in education and leisure ultimately were of crucial importance to American mathematics. But to the extent that natural philosophy and mathematics were championed by the clergy, their demise in influence may well have retarded the early study of mathematics for its own sake. The increase in economic opportunity had the effect that:

> *Instead of zeal there was simple piety and industry; scholars became less influential as the pioneer and the businessman became more important.* [Miller 1967, 45]

We get an indication of how the clergy stimulated mathematics and natural philosophy in New England when we observe that in the clergy-controlled colleges, courses in natural science were completely absent. [Hindle 1956, 81] In New England, where religious influence was strongest, there was no serious interest in botany until Cutler's paper appeared after the Revolutionary War. [Struik 1948, 47] The usefulness of natural science was certainly as apparent in New England as elsewhere; there were obvious benefits to both agriculture and medicine. But botany and natural science did not offer to the colonial mind a testimony of the reasonableness of the universe and the greatness of God.

Philadelphia replaced Boston and Cambridge as the cultural and intellectual center of the colonies; it also became the scientific center. It was in Philadelphia that the Enlightenment reached its zenith in the colonies. Here resided the leading colonial scientific mind, Benjamin Franklin, as well as the astronomer and mathematician David Rittenhouse, and the physicians Thomas Bond and Benjamin Rush. Philadelphia was the home of the wealthy James Logan, whose outstanding scientific library provided both a stimulus and nucleus for scientific activity. The only important scientific society in the colonies, the American Philosophical Society, founded in 1743, had its seat in Philadelphia. The combination of industrious German farmers and astute Quaker businessmen had created sufficient affluence to support science as a gentleman's pastime. Pennsylvania was also the colony with the least religious domination and the most religious tolerance. Of the nine colleges founded in the colonies before the Revolution, the only one that was nonsectarian was the University of Philadelphia (now the University of Pennsylvania).

Philadelphia had closer ties with the dynamic intellectual circles of England and Scotland. And it was also more open to French influence, including the influence of French mathematics. After Newton's death fierce nationalism, in the form of misplaced reverence for Newton and his notation for the calculus, had the effect of stifling mathematics in England. Hence, the colonies most closely connected to England intellectually, especially those in New England, suffered most from this influence.

The ultimate effects of the development of the mathematical sciences in Europe were felt in America far beyond the circles of the learned; these momentous events had diverse and far-reaching consequences. In 1758 a comet, whose return had been accurately predicted by Edmond Haley, appeared. [Hindle 1956, 96] To the medieval man few natural occurrences were as fearful and awesome as the startling appearance of a comet. But this time the comet had not been sent merely to signify God's displeasure with man; its occurrence had been accurately foretold by the new mathematical sciences. Yet in many ways the appearance of this new comet in 1758 was more of a portent than any comet of the Middle Ages. Its appearance was a testimony to the reasonableness of the universe and folly of superstition; it was symbolic of a new age. Indeed it was about this same time that the Great Awakening (1740-1750) brought about a shift from a medieval to a modern period. [Miller 1967, 82]

A number of forces combined in Elizabethan England to set the stage for the Industrial Revolution, that new idea of applying science to industry for commercial gain. The use of mathematics in science, by Galileo and others, had already supplied proved benefits to warfare. And the economic health of Elizabethan England gave hope of even greater prosperity. Bacon crystallized the concept that science was the servant of man in his *Novum Organum*:

> *For the chain of causes cannot by any force be loosed or broken, nor can nature be commanded except by being obeyed. And those twin objects, human knowledge and human power, do really meet in one; and it is from ignorance of causes that operation fails.* [Kaufman 1961, 8]

There is something democratic about Bacon's view. It describes a world in which the successful man is the man who can induct nature's laws, not the man who was born to power. It moves closer to Jefferson's natural aristocracy of talent, as opposed to an aristocracy of heredity.

The mathematical ideas that developed in the sixteenth and seventeenth centuries, and culminated in the achievements of Newton, had at least an indirect influence on American democracy. It seems more than accidental that deism, the religion inspired by Newton's *Principia*, was adhered to by both Jefferson and Franklin. The deist's tenet that God was the designer of the universe and the source of universal law discovered by Newton, suggests a universal civil law, or the inalienable rights of man in the Declaration of Independence.

According to the medieval view of the universe, the earth was a fixed planet of corruptible matter. The heavenly bodies were composed of tangible but incorruptible matter and were not subject to the physical laws that existed on the earth. Newton's discovery that the same laws governed both heaven and earth, radically changed man's concept of his universe; it influenced areas of western thought far removed from science and mathematics. It is not unnatural to ask in view of there being only one law on heaven and earth if there should be only one law for all men. Should there be a separate law for the nobles and yet another law for the clergy? Newton inspired free thought and discouraged superstition. And through the empiricist philosophers, especially Locke, his ideas influenced the political ideology of the American nation.

By the beginning of the Revolution, no mathematics worthy of mention had been done in America, and even casual interest in mathematics was not widespread. But the developments in science and mathematics in Europe had begun to influence the emerging nation. After the Revolution the lack of English restrictions on American industry would open the way for great technological development, and closer ties with France would breathe new life into American scientific and mathematical pursuits.

BIBLIOGRAPHY

Ball, Walter W. R. 1889 *A History of the Study of Mathematics at Cambridge*. Cambridge University Press, Cambridge.

Carman, Harry J., Harold C. Syrett, and Bernard W. Wishy 1960 *A History of the American People*. Alfred A. Knopf, New York.

Clinton, Dewitt 1815 *An Introductory Discourse, Delivered Before the Literary and Philosophical Society of New York, on the Fourth of May, 1814*. New York.

Cotter, Charles H. 1968 *A History of Nautical Astronomy*. American Elsevier Publishing Company, New York. The passage is quoted by Cotter. The "Doctrine of the Spheres" refers to spherical or mathematical astronomy.

Daniels, George H. 1967 "The Process of Professionalization in American Science: The Emergent Period 1820-1860," *ISIS* 58(2), 151-166.

——— 1971 *Science in American Society*. Alfred A. Knopf, New York.

Hindle, Brooke 1956 *The Pursuit of Science in Revolutionary America 1735-1789*. University of North Carolina Press, Chapel Hill.

Jones, Howard Mumford 1952 *O Strange New World*. The Viking Press, New York. This work extensively discusses medieval and

Renaissance influences in America.

Jorgenson, Chester E. 1935 "The New Science in the Almanacs of Ames and Franklin," *The New England Quarterly* 8, 555-561.

Kaufman, Walter, ed. 1961 *Philosophic Classics, Bacon to Kant*. Prentice-Hall, Englewood Cliffs, N. J.

Mason, S. F. 1953 *Main Currents of Scientific Thought*. Henry Schuman, New York.

Mather, Cotton 1721 *The Christian Philosopher: A Collection of the Best Discoveries in Nature, with Religious Improvements*. With an Introduction by Josephine K. Piercy. Scholars Facsimiles and Reprints, Gainesville, Florida.

Miller, Perry and Thomas H. Johnson 1963 *The Puritans*. Revised Edition, Vol. 2. Harper and Row, New York. The excerpt is from the tract "New England's First Fruits," published in London in 1643 to advertise the Massachusetts Bay Colony.

Miller, Perry 1967 *Nature's Nation*. The Belknap Press of Harvard University Press, Cambridge, Mass.

Morison, Samuel Eliot 1936 *The Puritan Pronaos*. New York University Press, New York.

——— 1961 *The Maritime History of Massachusetts 1783-1860*. Houghton Mifflin, Boston.

Phalen, H. R. 1946 "The First Professorship of Mathematics in the Colonies," *The American Mathematical Monthly* 53, 579-582.

Shipton, Clifford K. 1935 "A Plea for Puritanism," *The American Historical Review* 40, 460-467.

Simons, Lao Genevra 1925 "Algebra at Harvard College in 1730," *The American Mathematical Monthly* 32, 63-70.

Smith, David E. 1932-1933 "Thomas Jefferson and Mathematics," *Scripta Mathematica* 1, 3-14. A reproduction of Jefferson's letter is in *Scripta Mathematica* 1, 88-90.

Smith, David E. and Jekuthiel Ginsburg 1934 *A History of Mathematics in America Before 1900*. (Carus Mathematical Monograph Number 5.) Open Court Publishing Co., Chicago.

Struik, Dirk J. 1948 *Yankee Science in the Making*. Little, Brown and Company, Boston.

Voltaire 1779 *The Ignorant Philosopher*. Translated by Rev. David Williams. Fielding and Walker, London.

——— 1910 "On Descartes and Sir Isaac Newton," Letter XIV in *Letters on the English (Lettres Philosophiques)*. *The Harvard Classics; French and English Philosophers: Descartes, Rousseau, Voltaire, Hobbes*. P. F. Collier and Son, New York.

ACKNOWLEDGEMENT

The author wishes to thank Dr. Jean King and Mrs. Beth Esplin for critical readings of the manuscript. He also wishes to thank the referee, Dr. Dirk J. Struik, whose suggestions were vitally important in the revision of the paper.