MEMOIR

OF

THEODORE STRONG.

1790-1869.

BY

JOSEPH P. BRADLEY.

READ BEFORE THE NATIONAL ACADEMY, APRIL 17, 1879.

BIOGRAPHICAL MEMOIR OF THEODORE STRONG.

THEODORE STRONG, one of the original corporate members of this Academy, was born on the 26th day of July, 1790, and died on the first day of February, 1869, in the seventy-ninth year of his age. His birth took place at South Hadley, Massachusetts, at the house of his uncle, Col. Benjamin Ruggles Woodbridge, a prominent citizen of that place, who virtually adopted him as his own son. His father and grandfather both bore the name of Joseph Strong, and were Congregational ministers, descended from Elder John Strong, of Northampton, whose descendants, generally worthy of their Puritan ancestry, are scattered all over the land, and often found, as they have ever been, occupying positions of trust and responsibility. One of them is at this moment an honored associate of my own on the bench of the Supreme Court, being in the same degree of descent as the subject of this memoir, namely, the sixth degree from their common ancestor.

From this respectable lineage Theodore Strong inherited his vigorous constitution, as well as those solid elements of character which made him as eminent in purity and honor as he became in the walks of science.

His mother was Sophia Woodbridge, daughter of Rev. John Woodbridge, of South Hadley, the ninth generation of a succession of ministers bearing the same name, so that, on either side, Theodore Strong came from genuine Puritan stock. His ancestor John Strong was one of the first settlers of Dorchester, in 1630; and his ancestor John Woodbridge came to Massachusetts in 1634, and, returning to England, became one of the two thousand ejected ministers soon after the restoration of Charles II, and returned to this country as his permanent home in 1663. It is said of Theodore Strong's mother, Sophia Woodbridge, that she was a woman of very superior natural abilities, especially of the argumentative kind, and that in her younger days she was exceedingly beautiful. Men so

often inherit from their mothers their strong and healthy intellects and powers of reasoning that it has almost come to be a maxim of human experience that a man gets his mental ability from his mother. But Professor Strong's father is also said to have been a man of great energy, piety, and perseverance; but being blessed, like all of his ancestors, with a large family, he was not unwilling to permit his brother-in-law, Col. Woodbridge, who had no family of his own, to adopt his young son, Theodore, and take the responsibility of his bringing up and education. So it happened that the boy spent his early days in that beautiful region of mountain and farms where he was born. Of course he was early sent to school, where the spirit of emulation was first excited in him by a bright-eyed girl, who persisted in getting to the head of her class. Which of us has not had that same experience? At a proper age his uncle sent him to prepare for college with a neighboring clergyman, with whom he learned more accidence than he did arithmetic or algebra. At the age of eighteen he entered Yale College, then presided over by Dr. Dwight, the mathematical chair being occupied by Jeremiah Day, the chemical by Benjamin Silliman, and that of the learned languages by James L. Kingsley, with all of whom it became his good fortune to form associations of the greatest mutual respect and friendship. For the memory of President Dwight, in particular, he always retained the profoundest veneration. It was President Dwight, as he often remarked, who first taught him to think; and he was especially wont to speak of the benefit he received from the debates of the senior class held in Dr. Dwight's presence, and stimulated and guided into higher reaches of thought by his pungent questions and observations. "I could feel my mind *stretching*," he would say, "under the influence of Dr. Dwight."

Young Strong entered the freshman class very well prepared in the languages, but not much advanced in mathematics. At one of the earliest recitations in this department he made a failure, and was rather rudely laughed at by one of the class, which so excited his indignation that he turned to the offender, and, forgetting the proprieties of the place, said to him, quite audibly, "I'll teach you that I know as much about mathematics as you do!" From that moment he made up his mind to excel in that branch of study, and he kept his word to such purpose that when he graduated in 1812 he took the mathematical prize, and had already acquired such proficiency in the science as to attract the attention and friendship

of his teacher, Professor Day. His other studies had not been neglected, and he had become so deeply interested in Professor Silliman's department that at this period he formed the intention of pursuing the positive sciences, and especially chemistry. But it so happened that, shortly after his return home, Hamilton College, located at Clinton, in the State of New York, was in need of a mathematical tutor, and Dr. Azel Backus, the president of that institution, wrote to Dr. Dwight to inquire if any of the recently graduated class could be recommended for the position. Dr. Dwight unhesitatingly recommended Theodore Strong, and he was immediately appointed, and accepted the place. He remained at Hamilton College as tutor of mathematics for four years, and after that as professor of mathematics and natural philosophy for eleven years longer, and during that period laid the foundation of those profound acquirements in pure science which gave him such a high reputation amongst those engaged in similar pursuits throughout the country.

Thus, accident, in this instance, as in ten thousand others—or, at least, what appears to us as accident—cast the die which gave direction to a long and eminent life. Given a certain volume of brain and favorable circumstances for its development, and, from the observation I have made, I am convinced that the attainment of eminence in any particular department of science, or of active life, depends not so much upon any natural gift or aptitude therefor as upon other second causes, operating to lead the attention and energies in a particular direction. Men may be born poets or artists; that is, provided they cultivate poetry or art. For even here cultivation and practice are essential.

"For a good poet's made as well as born."

But in the special and particular development of the intellectual faculty I am sure that more depends on opportunity or chance than on any native genius or bent for a particular pursuit. Brain and opportunity are the factors of life. Nothing can be done without brain, of course, and nothing worth remembering without massive brain. But, given that, opportunity, often accidental in its character, does the rest.

Being a minute too late for the steamboat on the way to the metropolis to seek one's fortune may change the whole course of life; may lead to the college and the forum instead of the counting-

house and the exchange, and make a man to become what he never thought or dreamed of becoming. I have known just such a case. One man becomes an eminent divine instead of a lawyer; another an eminent mathematician instead of a merchant. Opportunity, accident, decided which it should be. Theodore Strong had brain, and a good store of it, and was, therefore, of capacity to become whatever Opportunity should set him to try for. She set him at mathematics, and he became a great mathematician.

When he received the invitation to the tutorship of Hamilton College he hesitated about burying himself in what was then regarded as the "Far West." But his uncle, who seems to have been a man of strong sense, and who undoubtedly exercised an indelible influence on his character, said to him: "Theodore, I have given you an education; now go forward and make a man of yourself!" He accordingly went; and perhaps the opportunities which he enjoyed for study and original investigation in that young institution were more favorable to his advancement in solid proficiency than a like position would have been in Yale, with its army of students and consequent tax on his time. Professor Day, in a letter addressed to him in December, 1813, says: "I have received yours of 15th November, and thank you for the communication of your ingenious discovery and demonstration of a property of the circle which I do not recollect to have seen in any author. I shall be gratified to hear from you frequently, and to learn from time to time what progress you are making in mathematical discoveries. I am very glad to see you placed in a situation where you have opportunity for investigation in your favorite science. I wish I had myself more leisure to devote to the higher departments of science. But as I am now situated I can do little more than endeavor to render truths long since discovered intelligible to those whom I am bound to instruct." The discovery and demonstration referred to by Professor Day were probably the demonstrations made by the young tutor about this time of the celebrated theorems respecting the circle, which had been propounded as a challenge to the world by Dr. Matthew Stewart in 1746. No demonstration had appeared until Mr. James Glennie, nearly sixty years afterwards, printed one in the Edinburgh Philosophical Transactions; but it is not probable that this had ever been seen by Mr. Strong. His attention was called to these theorems by one of the professors of Hamilton College soon after his going to Clinton. They had been recently published in

the 8th volume of Rees' Cyclopedia (article "Circle"), which was just being reissued in Philadelphia. In the then state of mathematical science in this country the demonstration of these theorems was undoubtedly a great feat of mathematical skill, which at once gave young Strong a very high reputation. It was sought for publication in the Memoirs of the Connecticut Academy. Professor Day, in a letter to Mr. Strong dated in August, 1816, says: "Your very ingenious demonstration of Stewart's propositions will be one of the most important papers."

A new and very neat and beautiful geometrical demonstration of the values of the sines and cosines of the sum and difference of two arcs, together with the solution of a difficult diophantine problem, was communicated by Mr. Strong to the first volume of Silliman's *American Journal of Science, published in 1818.* To the subsequent volumes of this journal he made a number of important contributions. One of these, in the second volume, contained the solution of a series of problems requiring the construction of a circle that should pass through given points and touch given straight lines or other circles, all solved in a geometrical way.

But having fully mastered the Newtonian Geometry as exhibited in the Principia and its commentators, he was now becoming deeply absorbed in the study of the higher analysis as developed by La Grange, Laplace, and other great mathematicians of the continent. To accomplish his purpose he resolutely set to work to learn the French language without the aid of a teacher, and became so well versed in it that he was able to read books pertaining to science as readily in French as in English. Whatever was necessary to be known in order to obtain a thorough comprehension of his chosen department he sedulously learned, stopping at no pains or trouble. Very few books in foreign languages were to be procured at that time without directly importing them. He accordingly imported such as were necessary for the prosecution of his studies, and when procured they were devoured with an appetite and digestion which made them a portion of his mental self. The science of mathematics to its profoundest depths was not merely acquired; it was absorbed into his being. He had no occasion to remember it; he knew it; not only in one relation and form of statement, but in all relations and forms. This was one of the peculiar features of his mental character, and lay at the basis of his real greatness as a mathematician, and at the same time explains some defects

of arrangement in his compositions, which will be adverted to hereafter.

In September, 1818, Professor Strong was married to Miss Lucy Dix, daughter of Captain John Dix, of Boston, a woman in every way worthy of him both in intellectual and moral accomplishments. An old friend whom he left behind at Yale, the brilliant and accomplished Professor A. W. Fisher (who afterwards met an early death whilst crossing the Atlantic), in a letter written at this time, rallied him in this wise on his newly assumed relations: "Matrimony and mathematics, I trust, in your hands will not get into a quarrel, as they have done in some cases. Newton, it seems, did not see how they could be made to agree; but the disciple of Newton appears resolved at least in making the experiment. May success attend him." And success did attend him. The lady whom he married was a woman of strong intellect and great good sense, and, instead of adding to her husband's burdens and interfering with his studies, relieved him in great measure from the detail of domestic cares, and by assuming them herself left him at leisure to pursue his favorite investigations without interruption or distraction. It is a happy lot when two persons of congenial dispositions are thus united; concurring harmoniously in the objects and duties of life, happy in each other, and contributing to each other's advancement in honor and usefulness.

Seven children were the result of this union, two sons and five daughters, one of the latter dying in infancy.

One of his daughters, the accomplished wife of the Hon. John W. Ferdon, at present a representative in Congress from the State of New York, gives this account of her father's mode of life and relations with his associate professors during the period of his connection with Hamilton College: "This period may be looked upon as the happiest portion of my father's life. The president of the college, Rev. Azel Backus, was a man of brilliant parts and of a most genial nature, and the professors generally were men of high attainments and ready sympathies. A most delightful fellowship prevailed among them. There was a great deal of what is called *esprit du corps*, and each man looked upon his associates' honor as his own. At this time the attention of scientific men was called to my father by his solution of several difficult mathematical problems. His correspondence also with scientific men was voluminous.

Letters dated at that time give us the best thoughts of such men as Silliman, Day, Fisher, and Olmstead."

Besides these more intimate associates and friends, Professor Strong early formed the acquaintance, either personally or by correspondence, of the most eminent men addicted to pure science on this side of the Atlantic, including Dr. Nathaniel Bowditch and Dr. Robert Adrain, and others of like proclivities and pursuits. The marriage also of one of his sisters to Dr. Benjamin W. Dwight, a son of President Dwight, and of another sister to Professor Charles Avery brought him into direct relations with men who could appreciate his worth and sympathize with him in his scientific inquiries. From one of his nephews, Rev. Benjamin W. Dwight, of Clinton, many valuable hints have been derived in the preparation of this memoir.

In 1825 and 1826 Professor Strong's increasing reputation was such that he received invitations to accept the chair of mathematics in Queens (afterwards Rutgers) College, in New Jersey, in Columbia College, New York, and in the University of Pennsylvania, all of which, however, were for various reasons declined. In December, 1827, receiving a second invitation of the kind from Rutgers College, he concluded to accept it, and removed with his family to New Brunswick. I cannot forbear again quoting from his daughter's memorandum. She says: "The journey to New Brunswick, the seat of Rutgers College, occupied at that time about a week. Several days of the transit were spent in slowly voyaging through the Erie canal. The now venerable Thurlow Weed, then a rising politician and editor, was a fellow-passenger, and the writer was kindly seated upon his knee during a great part of the journey."

At New Brunswick Professor Strong spent the remainder of his long life. Here he continued to pursue those abstruse studies and profound investigations, of which the outside world only obtained occasional glimpses in the articles contributed to scientific journals or academic societies, until the publication of his work on Algebra in 1859. Here the writer of this paper enjoyed his instructions, and learned to reverence his character and admire his great attainments. To give an idea of the manner of his life I cannot do better than to quote again from the memorandum furnished by his daughter, who, as before seen, was but a child when the family removed to New Brunswick. She says: "My earliest recollections of my father are of a man generally grave, thoughtful, absorbed in

his studies, yet occasionally unbending and engaging in frolic with us like a boy. He visited neighbors very rarely, and, except during his daily morning walk and hours of college duty, was generally found at home, always with book in hand. He was never annoyed by unfavorable surroundings, but would often sit in my mother's room, when his children were all at play around him, and enjoy with his book as complete abstraction of mind from all passing events as if he was alone in the universe. His table talk, however, is what I recall with most pleasure. All the phenomena of nature, as observable in passing events, were pointed out to our childish minds, and the question, Why these things were so? propounded to set our faculties at work—as, for instance, the condensation of vapor on our glasses in hot weather; how flies could walk on the ceiling, and many other questions of like nature; the derivations of the words we used also—which were from the Latin, which from the Greek, &c. He personally superintended our education, none of his daughters being sent to school for any length of time. In addition to his other duties he found time to instruct us in Latin, astronomy, and mathematics, and to require us to read aloud to him leading books of history, geology, and similar topics. He believed in the thorough education of woman, and I think it was a source of deep regret to him that none of his daughters gave any promise of emulating the fame of Mrs. Mary Somerville, whom he often spoke of as an example of what woman may achieve in the domain of science. As I grew older, and observed more particularly the books he read, I noticed that, though he found or made time for the perusal of general literature, with which he was remarkably conversant, yet his hours of deepest intellectual delight were found in the perusal of the works of Laplace, Newton, La Grange, and Plana. His life, thus to the busy world seemingly uneventful, glided away in the fulfillment of the duties of his position, the pursuit of knowledge, and the enjoyment of intercourse with men of science, many of whom came to consult him on points interesting to mathematicians."

The testimony of one of his intimate associates in professorial labor at this period is apposite here. Speaking of Professor Strong's breadth of culture, he says: "His love of books, and of a retired and contemplative life, enabled him to range over a wide and various field of knowledge. He 'sought and intermeddled in all wisdom.' He was largely read in history, in mental philosophy, in theology.

Among books it might perhaps be said that Bacon, Butler, Jonathan Edwards, and Dwight were his favorites. He cited occasionally, in conversation, those works of Bacon which are now rarely looked into. Bishop Butler's Analogy was his special delight. The suggestive—I had almost said hypothetical—way in which that great writer propounds truth made, he said, a deeper impression on his mind than the most vehement positive utterances. He had examined, with conscientious care and wide breadth of research, the evidences of Christianity. The question, What is truth?—in its relations to God and the soul—stirred his mind profoundly. His mental constitution and habits forbade him to yield his assent on any subject without sufficient evidence. His inquiries in this direction had resulted in a deeply-grounded and reverential faith."

Professor Strong's method of study, and that which he often impressed upon his pupils, was to study subjects rather than implicitly to follow books. In his case, as before remarked, it resulted in a complete absorption into his intellectual being of that which he attempted to master. With his strong and comprehensive intellectual grasp he seemed to arrive at results by intuition. In ordinary cases he could hardly have been conscious of the mental process by which his conclusions were reached. As all the propositions of mathematics are equally true and equally obvious to one who has a perfect comprehension of them, it necessarily follows that one who, like Professor Strong, sees each truth with equal clearness will scarcely note the progressive stages by which other minds, less gifted or less informed, are obliged to advance step by step in order to comprehend the more abstruse conclusions of the science. Hence it often occurred in his recitations that he would unconsciously get far ahead of his auditors, and much beyond their depth, until recalled to the actual situation of affairs by some question put by them or by himself which brought to his attention the distance which they had been left behind. This fact often produced the impression that he was not a successful teacher. But those who had in any degree a mathematical sense were well compensated by the striking originality of his views and the vivid light in which he often placed the subject under discussion. In his own mind his deductions were as clear as sunlight, and he made the scholar see them in the same way if he saw them at all. To those who had any taste for mathematical investigation he was a teacher to be desired; to those who had no taste for it he was sometimes unintelligible.

And yet it was astonishing with what perfect simplicity and clearness he would often render a profound truth, and all because it was so clear and simple to himself.

Perhaps it is often the case that the most successful teachers for the ordinary class of pupils, who require that the truths of science should be forced into them by extraneous aid, are those who have had to labor hard themselves to acquire those truths—men of slow parts, and at the same time solid understandings. They know the hard places. They can tell to a dot where it is and what it is that perplexes the young mind. They know just how to lead it step by step; just where to hold the lantern to it to enable it to pass smoothly and successfully over difficulties. In this there may be something due to natural tact; but I am inclined to think that this tact which we call natural is often the result of the teacher's own dear-bought experience. If it be true that this class makes the most successful teachers, taking the pupil world as it is, by and large, why, then, Professor Strong did not belong to it. He had marched with giant strides over the road which the student was obliged to creep.

But in speaking of the professor's unconscious tendency to diverge into regions where the ordinary student could not well follow him, it is but just to say that nothing gave him greater delight than to aid and assist those who seemed really desirous to learn; and in such cases he would spare no pains to simplify the subject under discussion, and set no limit to his patience in trying to remove every obscurity which beclouded the apprehension of the inquirers. His uniform condescension and kindness in this regard always won affection and respect, even from those who profited least by his instructions. Moreover, the remarks just made have reference only to the department of pure mathematics. In that of natural philosophy Professor Strong's teachings were most interesting and attractive, and always adapted to an ordinary capacity. Here, as in mathematics, he was profoundly master of his subject, which, having relation to the concrete manifestations of the natural world, he presented with such simplicity and familiarity of illustration that it was indeed a pleasure to listen to him, and the recitations were looked forward to with delightful anticipation.

I have often thought that it must be a most irksome task to a man of real ability and genius to be obliged, as many such men are, and as we have seen President Day complaining that he was,

to wear away their manly years in teaching, going over and over again the same course of mere elements, and endeavoring to inculcate them into just-dawning intellects. It is a great and a noble duty, to be sure, and its successful performance is attended with some consolations; but I apprehend that the greatest consolation which it affords is found in the leisure and opportunities which it often gives for pursuing, aside, the higher departments of science, and finding sympathy in that brotherhood of learned men whose silent and unpretending researches shed the richest lustre on any country.

Necessarily dry as were some of the subjects which Professor Strong was assigned to teach, he never forgot his responsibility to his pupils as a man and a Christian. Many an opportunity occurred, of which he failed not to avail himself, by a sententious or impressive remark, to fix in the minds of the young men around him those fundamental truths and principles which form the only true basis of character, happiness, and success in life. His solid sense and known worth were such, and his manner so unaffected and sincere, that no labored homilies could have produced so good an effect. He despised all sham and pretence. The coxcombry of prurient free-thinking in religion or morals was his detestation. Many a sturdy blow was given to these evil demons in a sentence or two of hard, New England sense—sentences which sank deep into the minds of the listeners and are still remembered, or have their effects to this day. Observations on the ordinary conduct of life were not omitted; sometimes serious, sometimes amusing or satirical, always sensible and just. Physical geography was at one time a branch of study on which he was required to give some lectures, involving to some extent the natural history of different regions. One day the subject of discussion somehow brought up the question of development of species and varieties, and thence led to the effect of breed and blood in horses and other animals. Suddenly, looking around at the class with great seriousness, he said, in his deep, bass tones, "Gentlemen, there is a great deal in this matter of blood. You will soon be thinking of marrying and settling in life. Much of a man's happiness and success depends on his choice of a partner. My advice to you is look to the blood; there is a great deal in blood!" and then he quietly proceeded with the recitation. This is but a slight illustration of the manner in which he would interject remarks on subjects of practical interest as well as on those of a higher nature.

Of course they were often expanded into forms of rich and earnest thought, which never failed to produce a deep and lasting impression.

The amount of influence which such a man exerts through a long life upon the successive classes of young men that come in contact with him, and through them upon society and those who give it tone and power, cannot well be computed.

Age, however, began to creep apace upon the good professor, and in 1859 the trustees of the college, probably somewhat influenced by the impression alluded to in reference to the supposed deficiency of attractiveness in his method of teaching, deemed it advisable to appoint an associate professor in his department, thus relieving him to a large extent from active duty in the class-room. It was at this period that he brought out his work on Algebra. At the same time, feeling conscious that he was still in possession (as indeed he was) of all his intellectual powers, he did not submit kindly to what he deemed an attempt to ignore his usefulness. In 1861, now in his 72d year, he was relieved from active duty, and declared emeritus professor. In 1863 he resigned all connection with the institution, and passed the remainder of his life in the prosecution of his favorite investigations in analytical science, and in the enjoyment of that society of the learned dead and of the few remaining associates of his earlier years who yet survived, as well as in the respect and reverence of all who knew him and had learned to appreciate his great abilities and sterling character.

In 1859, as already stated, Professor Strong published his Treatise on Elementary and Higher Algebra, a work remarkable for its originality and depth. His treatise on the Differential and Integral Calculus was principally written in the summer of 1867, in the 78th year of his age, whilst on a visit to his nephew, Rev. B. W. Dwight, at Clinton, and was not published until after his death. Perhaps no other treatises on these subjects exhibit in an equal degree so much logical power and such profound acquaintance with fundamental principles. The student is conducted, often by fresh and untrodden paths, to the highest eminences of the science, and may always repose the utmost confidence in his leader's keenness of vision and sureness of foot hold. For notwithstanding Professor Strong's profound knowledge of his subject, and his immense learning, embracing, as it did, a thorough acquaintance with the whole body of mathematical science, both ancient and modern, and perfect famil-

iarity with all that had been written by Newton, La Grange, Laplace, Poisson, Ivory, Airy, Le Verrier, and others of like eminence and power, he was, nevertheless, always extremely cautious in accepting his own conclusions, and made it his habit carefully to review, over and over again, his demonstrations and solutions of problems, in order to be perfectly sure of their correctness before offering them to the inspection of others.

His arrangement, however, is not always the most happy for those whose knowledge is not considerably advanced, abstruse discussions, though logically consecutive to what precedes, being frequently introduced before a mere learner can be presumed qualified to comprehend their import. Thus, in the Algebra, after giving a lucid and masterly explication of the rules and principles of multiplication, he quietly proceeds to unfold the method of constructing equations by the multiplication of successive binomials, and does not leave the subject until the whole doctrine of the roots of equations is established—beautifully established, it is true, to those who are capable of following the discussion, but not discussed at a time when a beginner in the science would be likely to be edified. Another instance of the anticipation of abstruse inquiries is found in the section on Geometrical Proportions and Progressions, at the close of which the student will be surprised to find demonstrations of the theorems of Taylor and Maclaurin and of the principle of differential coefficients. Whilst these discussions are most satisfactory, and are, indeed, strictly algebraical, and whilst they show the marks of a great original mind, and possess the highest interest for those who are already proficient, or at least quite advanced, in analytical investigations; they are not well adapted to the comprehension of mere students in algebra. Perhaps it is but just to say, however, that this introduction of abstruse subjects should not be deemed irrelevant in a work which professes to treat as well of the higher as of the elementary parts of the science. But as such higher parts are only interesting to a chosen few, the effect is to load the book with too much weight for popular appreciation.

This defect of arrangement, or, if it be more proper to say, this introduction of abstruse, though perhaps necessary, discussion—necessary to a complete view of the subject in all its relations and adaptations—is probably the true reason why these works have not been appreciated by the public as their merits deserve. The work on Algebra not meeting with a ready sale, the whole edition, save a

few copies, was destroyed by the New York book-sellers into whose hands it fell after the failure of the publishers. Thus, from a want of ready appreciation, one of the most original and profound works on pure science which this country has ever produced has become so scarce that a copy is now hardly to be met with. Here and there an industrious investigator, who happens to possess one, will draw from it, as from a rich mine, things of beauty and value, which, garnished with new settings, will bring to the finder reputation and honor. If he happens to be a man of justice and candor he will award to his master that tardy recognition which alone is all that true greatness often receives in this world.

Whilst preparing his work on the Calculus, which he proposed to publish at his own expense, some friend expressed apprehension that, from the nature of the work, it would not be a pecuniary success, but money thrown away. His reply was characteristic. "No matter," said he, "it will be appreciated by posterity, and show at least that I have not lived in vain; and that is all I ask!"

Of these two works, the Algebra and the Calculus, it does not become me to speak in detail with any pretension of authority. As already stated they are not books for ordinary college students—they go too deep for that. But I think I am not mistaken in saying that no real student of analytical science, who desires to understand it in all its depth and power, can read these books without being greatly instructed and refreshed. For original investigation and profound knowledge of the subject they cannot be excelled. They certainly, also, contain many things entirely new in the sciences of which they treat. For example, the solution of Cardan's irreducible case of cubic equations in the Algebra has accomplished what the mathematical world had for centuries sought to accomplish in vain. Its practical value, however, since the elegant method discovered by Horner for solving all numerical equations, is not great. It involves the extraction of a number of successive square roots, which makes the operation somewhat tedious. But this does not derogate from the merit of Professor Strong in producing a rigidly logical solution, which had defied the efforts of all previous mathematicians.

In the able review of the Treatise on Algebra in Silliman's Journal for September, 1860, it is said "this work does not belong to the class of elementary compilations with which our schools and colleges are so abundantly supplied, but is a fresh and original

treatise, stamped on every page with the peculiar impress of the author's mind. It contains, moreover, several positive additions to the science, while many of the demonstrations of well-known propositions are new and highly suggestive." Again, "Dr. Strong has risen to such heights in the science, and has so long been an industrious explorer on its confines, that he has lost sight of the paths by which the novice must necessarily be introduced. But, assuming the reader to have acquired a fair knowledge of algebra, including the general theory of equations, we would recommend him to read this work as a *review*, in which the science is rearranged in a special order, and a new light is thereby thrown on many of its processes. For Dr. Strong is a master of his subject, and handles the most difficult parts of it with something of that giant ease which we feel and admire so much in the great Euler." And after discussing the new solution of the irreducible case of cubic equations he says: "This method, therefore, may be justly claimed as an addition to the science, as well as the solution of binomial equations, the new demonstration of the binomial theorem, the development of the roots of equations, series, etc.; all of which will be read with pleasure by advanced students."—(*Am. Jour.*, vol. xxx, p. 306.)

As it may be interesting to know what things in the Treatise on Algebra Dr. Strong himself regarded as new I shall here take the liberty of copying a statement on this subject furnished by him to an intimate friend interested in mathematical inquiries. Besides the solution of the irreducible case the following items are specified:

1st. A new and direct investigation of the binomial theorem. (Page 271, &c.)

2d. A new and very simple method of finding integral algebraic roots. (Page 284, art. 6.)

3d. A new and very simple proposition of great use in extracting the roots of quantities of the form $1 + \frac{b}{a^r}$, by resolving them into any number of factors of the like form. (Page 288, art. 8.)

4th. A new and very simple method of solving quadratic equations without the formality of completing the square. (Page 397, art. 2.)

5th. New formulas by which to solve equations by the immediate development of their roots without finding their first figures by trial, as is usually done. (Pages 439, 440, formulas (b) and (c).

6th. The doctrine of continued fractions deduced immediately

from the form of the quotients and remainders in common division. (Page 443, &c.)

7th. A new demonstration of the method used for finding the limits of the real roots of equations, including the theorem of Des Cartes. (Pages 471, 480.)

8th. A new method of developing the real and imaginary roots of equations. (Page 449, § 19.)

9th. A new and much more simple method than that of Sturm for finding the first figures of the real roots of an equation. (Page 512.)

10th. A new and simple method of resolving whole numbers into their factors. (Page 535, § 21.)

The late Professor De Morgan, of London, a high authority on such subjects, receiving a copy of the book, expressed himself in terms of admiration of its ingenuity and of the importance of some of the above improvements.

As to the work on the Calculus I can only say that the subject is investigated from its fundamental principles in such a thorough manner that no one can study the book without acquiring a better comprehension of the science than he ever had before. As has been justly observed, the processes of integration employed are so excellent in themselves, while being at the same time original, as to seem even elegant to a mathematical eye. The difficulties that had embarrassed the previous treatment of the first principles of the Differential Calculus are eliminated. The infinitesimal method of Leibnitz and the method of limiting ratios of Newton are shown to be unnecessary in a proper conception of the science. Of course in this general view Dr. Strong follows La Grange; but he demonstrates it in such an original way that it seems new, and makes the conclusion perfectly obvious and satisfactory. By an explanation of his own, which is purely algebraical, he divests the Calculus of all its old metaphysical incumbrances, which were the stumbling-blocks of so many ingenious minds. On page 266 is the solution by a new and beautiful method of the problem "to find the area bounded by the ordinate of a plain curve drawn through the origin of the co-ordinates, by any other ordinate, and the intercepted parts of the axis and the curve, supposing the ordinate to be constantly positive between the preceding limits"—being the same figure used by Newton to demonstrate his celebrated Lemmas, II, III, and IV. Having

solved this apparently innocent problem by a course of demonstrative reasoning, the author shows how it results in establishing the foundation principles of the Calculus without the intervention of any of those antiquated hypotheses to which we have referred. "It is hence clear," says he, "that the Differential and Integral Calculus are deducible from what has been done without using infinitesimals or limiting ratios." (Page 271.)

If we may believe those most competent to judge, the book is full of interesting discussions which, to one who is at all familiar with the ordinary modes of treating the subject, are as refreshing and exciting as it is to travel over a new country, which one has never visited before, and which is filled with picturesque objects and beautiful and varied scenery. To those who have no taste for analytical methods of investigation it is a sealed book; but to those who have such a taste, it is fraught with interest and instruction, in consequence of the fresh and original manner in which every subject is treated. It evidently flows from a mind full of the subject, and disdaining to copy from others where original treatment is capable of placing it in new and interesting lights.

As before remarked, Professor Strong was a contributor, during the greater portion of his active life, to various mathematical journals and to learned societies, of which he was a member. His solution of questions and his general discussion of subjects were always marked by profound knowledge of the subject in hand and a complete mastery of the best methods of treating them. Being one of the first in this country to acquire a thorough knowledge of analytical science as exhibited in the works of the mathematicians of France, Germany, and Italy, he brought to these solutions and discussions an ease, a generality, and a comprehensiveness which always excited the admiration of his colaborers. By the aid of a mathematical friend I am enabled to give a list of the principal journals in which these miscellaneous papers appeared. These are—

1. Silliman's American Journal of Science. Twenty-two papers of Professor Strong's are published in the first series of this journal, extending from 1818 to 1845.

2. The Mathematical Journal, published in New York, of which only one volume appeared.

3. The Scientific Journal, edited by Mr. Marrat, and published at Amboy, in monthly numbers, of which nine in all appeared in 1818 and 1819.

4. The Mathematical Diary, published at New York, and edited at first by Dr. Robert Adrain and afterwards by James Ryan.

5. The Mathematical Miscellany, edited by Mr. Charles Gill, at St. Paul's Collegiate Institute, Flushing, Long Island. There are twenty-two papers by Dr. Strong in this periodical. Mr. Gill subsequently became the eminent actuary of The Mutual Life Insurance Company of New York.

6. The Cambridge Miscellany, edited by Professors Peirce and Lovering. Seven of his papers are published in this periodical.

7. The Mathematical Monthly, edited by J. D. Runkle. Two of Dr. Strong's papers are published in this work.

Besides the above he made various communications to the Connecticut Academy, of which he was elected a member in 1815; to the American Philosophical Society, of which he was elected an honorary member in 1844, and probably to the American Academy of Arts and Sciences at Boston, of which he was also a member. He also communicated his solution of cubic equations to the Smithsonian Institution in 1849, which was not published at the time, in the hope, as Professor Henry wrote to him, that he would add to it some other papers, so as to make a more considerable article for the Contributions.

He also communicated five different papers to The National Academy of Sciences, from 1864 to 1867, inclusive.

No doubt many others could be found by a diligent search of the scientific journals published during the period of his active labors.

The papers published by him in Silliman's Journal are in the form of discussions of various subjects to which he was giving his particular attention at the time. Collected and arranged in the form of a book they would constitute a useful commentary on many difficult portions of the Mécanique Céleste and cognate works. These papers are characterized by the Professor's usual originality of treatment, and often throw important light on points that were left obscure by the great authors whose works he was studying. Dr. Bowditch's translation and commentary have undoubtedly supplied nearly all that is wanted to the proper understanding of the Mécanique Céleste; but it may well be supposed, as the fact undoubtedly is, that Professor Strong, whose study of Laplace's works had long preceded the publication of the translation, has often taken original and independent views which would greatly aid in a complete mastery of the whole range of subjects treated of.

I can here only give a list of the papers referred to, and specify the various subjects discussed. Besides the geometrical problems in the first and second volumes of the Journal, already mentioned, we have the following:

1. A new and entirely original demonstration of the binomial theorem, in volume 12, page 132.

2. A systematic discussion of the laws regulating the action of a central force, the path of the curve produced thereby, and the mutual action of a system of bodies. These papers, which constitute a valuable monograph on the subject of central forces, are twelve in number, and are contained in the 16th to the 26th volumes of the Journal.

In the course of this discussion, in volume XVI of the Journal, page 286, we find a beautiful deduction of the differential equation which constitutes the fundamental formula for expressing the angular velocity of a planet in terms of its radius vector, and thence, the force being given, the law of the curve of revolution, and of all curves produced by a central force, corresponding to the result given by Laplace in the first part of his 2d book of the Mécanique Céleste, Equation (3), and to that of Newton in the 41st proposition, section VIII, of the Principia. This, however, is but a single instance of many similar correspondences which illustrate and simplify the grand results established by these great masters of the science, sometimes with greater generality and comprehensiveness.

3. A discussion of the parallelogram of forces, their composition and resolution, and the statical equilibrium. Here we have the groundwork of a treatise on analytical mechanics. This is comprised in three separate papers contained in volumes 26, 28, and 29 of the Journal.

4. In volume 30 we have a paper on the variations of the arbitrary constants in elliptic motion.

5. In volume 42 we have a paper entitled "A new demonstration of the principle of virtual velocities," rewritten and inserted in an improved form in volume 43.

6. Volume 42 also contains a paper on the integration of a particular kind of differential equation of the second order—being a more general and more accurate integration than that given by La Croix of the same equation, and including a particular form of it, propounded in Prof. Peirce's Mathematical Miscellany.

7. In volume 45 there is a paper containing Remarks on the First

Principles of the Differential Calculus, together with a new investigation of Taylor's theorem.

8. Volume 48 contains a paper entitled "A new way of obtaining the exponential and logarithmic theorems"—which, as I remember, the Professor explained to us many years before when I was attending his lectures in Rutgers College.

The *Mathematical Diary* was commenced in 1825 and continued to 1832. It was conducted with much ability and was the vehicle of many difficult solutions of problems by the highest mathematical talent of this country. Its contributors, besides the learned editor, were Dr. Bowditch, Professor Strong, Professors Anderson, Quinby, Nulty, and others. A series of select questions were proposed in one number and answered in the next. Every successive number announced that all the questions had been solved by Dr. Bowditch and Professor Strong, sometimes one or two others being added. In most of the numbers some question of great difficulty would be proposed, called the prize question; and whoever, in the estimation of the editor, or of a committee taken into council on the subject, gave the most satisfactory and elegant solution, would take the prize, which was simply the honor of having the number containing the solution called by his name. The second number of the journal, containing such a solution by Dr. Bowditch, was called The Prize Number of Nathaniel Bowditch. The third number was called The Prize Number of Theodore Strong. And, by the way, the problem solved by him in this instance is one of the most difficult and elusive that can be attacked by the ordinary analytical processes. It is called the boat problem, and requires an investigation of the path that ought to be described by a boat in crossing a river of given width from a given point on one side to a given point on the other, so as to make the passage in the least time possible, supposing the simple velocity of the boat by the propelling power to be given, and that the velocity of the current, being in the same direction with the parallel sides of the river, is variable and expressed by any given function of the perpendicular distance from the side of the river from which the boat sets out. The curve required is analogous to the curve of pursuit described by a spider, starting at a given point within a circle, or in its circumference, and chasing a fly which starts at another given point of the circumference and follows it in a given ratio of speed to that of the spider. The solution of Professor Strong is most ingenious and satisfactory, and is

inserted by him in the appendix to his work on the Calculus, with a practical exemplification, by means of a figure, adapted to a particular case.

The *Mathematical Miscellany*, edited by Mr. Gill, except that it contained more discussions of a general character, was in most respects similar to the Diary, and was published twice a year, from 1836 to 1839, inclusive. Amongst its contributors were Professors Strong, Avery, Peirce, and Catlin. Some of the problems required in their solution the very highest range of mathematical skill, and, as in the Diary, the periodical announcements showed that solutions to all of them were furnished by Professor Strong, this distinction being shared by only one or two others. The sixth number contained a paper by him on the orthographic projection of the circle, which Professor Peirce characterized as "beautifully neat."

In the proceedings of the American Philosophical Society of Philadelphia for the year 1843 I find a short paper of Professor Strong's on Analytical Trigonometry, and in the same volume a paper on the transformation of the series, $S = ax + bx^2 + cx^3$, &c.

The papers communicated by him to the National Academy were, (1st), Notes on the parallelogram of forces and on virtual velocities, March, 1864; (2d), On the integration of differential equations of the first order and higher degrees, August, 1864; (3d), A new theory of the first principles of the differential calculus, August, 1865; (4th), A new theory of planetary motion, August, 1866; (5th), On a process of integration used in the case of a planet's orbit disturbed by small forces, August, 1867.

Of course, some of the subjects treated of in the foregoing list are again discussed in the Algebra or the Calculus, but never, or rarely, in the same form; for, as before stated, the truths of mathematical science lay in Professor Strong's own mind, ready to be drawn out in original forms, and he rarely copied, even from himself, but relied on the resources of his own intellect.

Thus, in the brief memorial furnished by his nephew, Rev. B. W. Dwight, I find the following interesting account of the manner in which Dr. Strong prepared his work on the Calculus. Mr. D. says: "The writer was in almost daily intercourse with him when he was writing his Calculus in Clinton, and was active in inducing him not to fail to do so, and states what he knows to be true when he says that in preparing this great work for publication he brought it forth in its present complete state from the independent action of

his own mind at the time, without the aid of any separate notes or books. It had lain for years in, as it were, chemic solution in his thoughts, and was then precipitated by an act of will into its present form of presentation to others' eyes.

"His memory," says Mr. Dwight, "was not so remarkable as his reasoning faculties. It was never the habit of his mind to undertake to recall its previous mathematical solutions or mental processes. The writer asked him, when he had finished writing out his Calculus, whether, if it should be destroyed, he could write it all over again from memory. He answered, at once, 'No! not at all; but I could write it out anew again from my knowledge of the subject.'"

To this I may add that he was never satisfied to accept at second hand the demonstrations or conclusions of others, however eminent or high as authorities, but always sought to bring out the same result (if true) from some new and self-evident hypothesis, or by some new process of reasoning, generally exhibiting not only striking originality of conception, but a profound knowledge of the entire subject and the principles involved in it.

It is undoubtedly true that in pure mathematical science Professor Strong was a very giant. Other stars of great brilliancy and splendor have since risen in our scientific hemisphere, some of whom have been mentioned in this memoir; but in his day he had hardly a peer in grasp and power of intellect. Between him and Dr. Bowditch there seems to have existed the greatest mutual esteem and regard. If the latter, on account of his age and great attainments, was regarded as *princeps* amongst the mathematicians of this country, to him alone Professor Strong stood *secundus* in the public estimation. Their studies lay in the same direction, and, although the senior of the two was the first to enter the field of transcendental mathematics, yet it is questionable whether Professor Strong was not fully his equal in profound knowledge of the science and the application of its methods to the most difficult problems. His ability was so generally recognized at the period of his settlement in New Jersey that a prominent mathematician of New York, who about that time published a series of difficult problems, which he challenged all the mathematicians ir America to solve, expressly excepted Dr. Bowditch, Professor Strong, and one other. But there was no feeling of rivalry between these two great men. Professor Strong always cherished for Dr. Bowditch the deepest reverence

and respect. One of the treasures of his library, most highly prized, was a presentation copy of the translation of The Mécanique Céleste. He had himself studied the original for many years, and had made valuable comments on its most difficult parts; and it must have been to him a source of intense satisfaction to follow Dr. Bowditch over the ground which had been so successfully trodden by both. To these two men, perhaps, more than to any others (unless Dr. Adrian should be added) are we indebted for the introduction of the study of the higher mathematics in this country. It may be added that at Dr. Bowditch's death his family were anxious that Professor Strong should prepare a review of the translation of Laplace, to be inserted in Dr. B.'s biography, and which he expressed a willingness to do; but it seems that the project was, for some reason, never carried out.

Professor Strong, besides being elected an honorary member of the learned societies already mentioned, to wit, The Connecticut Academy of Arts and Sciences, at New Haven, in 1815; The American Academy of Arts and Sciences, at Boston; The American Philosophical Society, at Philadelphia, in 1844, and being appointed one of the original members of The National Academy of Science in 1863, received the honorary degree of doctor of laws from Rutgers College in 1835, and also the same honorary degree from Hamilton College. A much higher testimony to his worth as a man and a professor is found in the universal expressions of esteem and regard with which his name was ever mentioned by those with whom he daily associated, whether professors or students. Hon. A. B. Hasbrouck, who presided over Rutgers College for ten years, from 1840 to 1850, thus speaks of him: "Through the whole course of my office there he was my counsellor and guide, ever ready to advise and assist in all emergencies. It is due to the several classes that passed through the college during my presidency to say that, through his prevailing influence, wisely supplemented by that of our estimable associates, very little embarrassment of discipline occurred—a paternal government met with filial obedience and regard, and scarcely a ripple occurred upon the smooth plane of study and conduct. Professor Strong always carried into his lecture-room the sunshine of his cheerful temperament. Ever ready to applaud a successful recitation he was equally so, by kind and patient assistance, to help the faltering or delinquent in the lesson of the day. No student ever left his room smarting under a

sarcasm or disheartened under a severe rebuke. On the contrary, he habitually planted there, with the seeds of useful knowledge, the germs of affectionate remembrance. In the course of a long life I have met with few men whose characters have exhibited more admirable traits or fewer blemishes to mar their worth. Simple in his manner, courteous in intercourse with all classes of men, tolerant of the opinions of others, but ever ready without offence to uphold his own, honest in the higher sense of moral obligation, constant in his friendships, he held in permanent possession the respect of all who knew him well. Never presuming to scan the mysteries that lie beyond the bounds of human research, he walked humbly in faith, and, after a life of usefulness and virtue, we may believe, according to human judgment, that he will at the great day hear the welcome awarded to a good and faithful servant."

This is but a fair specimen of the testimony to the excellence of Professor Strong's character ever rendered by his associates. The attachment and respect of his pupils here spoken of are not in the least overstated, as is shown by extant testimonials of graduating classes and individuals, and as known and felt by hundreds yet living. Doctor Edward Robinson, the distinguished oriental scholar, who was graduated at Hamilton College, once said that the one man in the world who had most of all roused him to high aims and efforts was Professor Strong. Gerritt Smith, another of his pupils, wrote thus of him in November, 1874: "Hamilton College, my honored mother (especial thanks to Norton and Strong, of blessed memory), taught me a large share of the little that I know, and would have gladly taught me more had I only been more teachable."

Professor Strong was an earnest patriot; a Federalist in his views, as may be supposed from the school in which he was trained; always alive to the political movements of the day; always decided in his convictions with regard to passing measures, topics, and men, and always ready to express his opinions. It was never doubtful where he stood. And it may be added that his country's honor, her greatness and her glory, were ever dear to him.

In person he was a little over the middle height, solidly built, and erect and commanding in figure. He enjoyed a vigorous constitution by nature, and preserved it by temperance and habitual exercise. He had a most benign as well as intellectual expression of countenance, at the same time indicating much positiveness of conviction and general firmness of character. He was, as his nephew

truly describes him, a thorough Christian gentleman. With a manner in social converse decidedly abstract in respect to any formal conventionalities, he was one of the most genial of visitors and talkers. Fond of being questioned on matters of general or special scientific interest and naturally addicted to logical discussion and disputation, he liked particularly to have theological tilts with those who differed from him in their views. He was a habitual reader of the Bible, an observer of the Sabbath, and a regular attendant on public worship. His heart was always full of the moral momentum of the age, and he kept himself at all times well informed, with studious earnestness, of the passing events of the day, nor was he slow to accept the new ideas and efforts which they suggested in respect to the moral, social, or religious progress of the race. He had an abiding sympathy for the oppressed in all parts of the world and a recognition of man as man, aside from all differences of class. He was ever ready to aid the poor and distressed, and some of the most heartfelt grief shown at his grave was manifested by laborers whom he had employed, and who revered him as a sympathizing friend and adviser.

The last years of his life were saddened by the death of his youngest son, Theodore, who died of malarial fever in the army during the late war, in the twenty-fifth year of his age. From this terrible blow he never entirely recovered, and only partially forgot his grief when absorbed in those speculations which had constituted the chief interest of his life. In these, as we have seen, he was engaged to the last, and when the weary frame and over-taxed brain finally gave way it was touching to those who, in his latest moments, watched by his side to witness the efforts of the wandering mind to grasp at the solution of problems which ever seemed to evade him.

Shortly before his death he made a public profession of his religious faith by partaking of the sacraments of the Church. When the pastor and session entered the room he raised his head from his pillow and addressed them as follows: "Gentlemen, I have called you here that I might discharge a most important and too long neglected duty." But he had lived a Christian all his life, had ever borne testimony to his firm belief in all the fundamental truths of religion, and was always decided and outspoken in favor of virtue and in condemnation of vice in all its forms. And, after all, a good life is the best evidence of religious character. If the object of religion is not to make men better, what is it?

Dr. Strong departed this life on the first day of February, 1869, in his seventy-ninth year. To sum up all, we may say, in one word, he was a virtuous, lovable, and manly man; great in his special department, faithful in all his house, and true to the generation in which he lived. It is right that we should honor him in our memories and not neglect to speak his praise.