MEMOIR

OF

JOSEPH SAXTON.

1799–1873.

BY

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BIOGRAPHICAL MEMOIR OF JOSEPH SAXTON.

MR. PRESIDENT AND GENTLEMEN OF THE ACADEMY:—

AT the last session of the National Academy of Sciences I was appointed to prepare an account of the life and labors of our lamented associate, Joseph Saxton, whose death we have been called to mourn. From long acquaintance and friendly relations with the deceased, the discharge of the duty thus devolved upon me has been a labor of love, but had he been personally unknown to me, the preparation of the eulogy would have been none the less a sacred duty, which I was not at liberty on any account to neglect. It is an obligation we owe to the Academy and the world to cherish the memory of our departed associates; their reputation is a precious inheritance to the Academy which exalts its character and extends its usefulness.

Man is a sympathetic and imitative being, and through these characteristics of his nature the memories of good men produce an important influence on posterity, and therefore should be cherished and perpetuated. Moreover, the certainty of having a just tribute paid to our memory after our departure is one of the most powerful inducements to purity of life and propriety of deportment.

The object of the National Academy is the advancement of science, and no one is considered eligible for membership who has not made positive additions to the sum of human knowledge, or in other words, has not done something to entitle him to the appellation of scientific.

Joseph Saxton, the subject of our eulogy, was named in the Act of Congress organizing the Academy, one of its fifty original members, and I trust the following sketch of his life and labors, imperfect as it may be, will fully justify the propriety of the distinction which was thus conferred upon him.

He was born in Huntingdon, Pennsylvania, then a small village, on the banks of the Juniata, on the 22d of March, 1799, and died in the city of Washington, October 26th, 1873. He lived, therefore, within five months of three-quarters of a century. During his life the world made greater progress in the application of science to art than in any other period of equal length in all of its previous history. To illustrate this remark I have only to recall the fact that during this period the steamboat, the railway, the locomotive, the electric telegraph, the photograph, and the spectroscope had their birth.

It might be an interesting inquiry to determine what effect was produced on his character by the direction of the energy and the prevailing thought of the age in which he lived. Be this as it may, our associate found in the period of his life congenial tendencies, and he had the good fortune, denied to many, of neither being behind nor in advance of his age, but of being in perfect harmony with it. He neither pestered the world with premature projects destined to failure because the necessary contemporaneous conditions were not present; nor retarded the advance of improvement by advocating old errors under new forms. On the contrary, his inventions were founded on well-established principles, and consequently were positive additions to human power and efficiency.

Mr. Saxton in early life had few advantages of education, nothing more than what was afforded by an ordinary common school, but he possessed a mind of general powers which enabled him to grapple with a large class of subjects; and an imagination which teemed with new conceptions, especially in the form of scientific inventions. Whether these traits had been especially manifested in any of his progenitors, I have no means of ascertaining. His father was James Saxton, who with his wife Hannah Ashbaugh, was the parent of eleven children, of whom the subject of our sketch was the second. James Saxton, the father, was a man of talents, but did not apparently apply them persistently to one pursuit. He occupied in succession the position of an assistant in a banking establishment, a justice of the peace, and that of a proprietor of a nail manufactory, the first ever erected in the part of the country in which he resided. He was of English descent, his wife belonged to one of the German families of Pennsylvania, and was noted for her good common sense and efficient housekeeping.

At the age of about twelve years Joseph was put into his father's nail factory as a working hand, and soon evinced his talent for invention by an improvement in the machinery which added materially to its efficiency.

Becoming discontented with the monotony and mechanical drudgery of the nail factory, at his earnest solicitation he was apprenticed to the village watchmaker, but after being in this occupation for about two years he was thrown out of it by the death of his employer.

After this he amused himself with the construction of a printing-press and the publication of a small newspaper, irregularly issued. His first speculation in the line of science was an attempt to explain an accident which nearly cost him his life. He had become the possessor of a new rifle, and on loading it for the first time, after putting in the powder and inserting the ball covered with its greased patch, he found to his surprise that, on attempting to push down the ball with the ramrod, it sprung back, in one instance with such velocity as to project the rod out of the barrel. Determining to force down the ball whatever the resistance might be, he placed the projecting end of the rod against the trunk of a tree, and then with the momentum acquired by the weight of the gun gave a powerful push, which was attended with a result entirely unexpected. The ball was indeed forced in, but, in overcoming the resistance, an explosion took place, which shattered the ramrod into fragments and prostrated him at full length, almost lifeless, on the ground. Reflecting on this incident, which could not fail to make a deep impression on his mind, he came to the conclusion, probably by the analogy of the heat evolved in hammering a nail, that there is heat in the air, and that, by the violent pressure to which he had subjected it in attempting to urge down the ball, he had pressed out this heat, and thus fired the powder.

Learning by subsequent inquiry that his hypothesis was in accordance with received principles of science, he was naturally awakened to the consciousness of the possession of powers of original thought—a discovery which was undoubtedly attended with pleasurable emotions, and which would in no small degree promote self-confidence.

He had now arrived at the age of eighteen. Conscious of mental power, and desirous of extending his sphere of action and his means of acquiring knowledge, he resolved to leave his home and seek his fortune in Philadelphia, the fame of which had often excited his youthful imagination. In this enterprise he induced two of his companions of about the same age as himself to join. They first repaired a boat which he had previously constructed as a large model of a man-of-war, and, after furnishing it with a supply of provisions and placing on board all their worldly effects, they launched forth, and were rapidly borne by the current of the river on their adventurous voyage, with but little need of aid from oar or sail. The news of the intended departure of the trio produced in the isolated village of Huntingdon quite a sensation, and called forth much discussion as to the probability of the project being abandoned before the adventurers had passed the neighboring settlement, five miles below. Indeed, so great an interest was awakened in this question that a considerable number of their friends and acquaintances accompanied them along the bank to the village just mentioned with the expectation of seeing them give up what appeared to be a foolhardy undertaking. But this occurrence served but the more to induce perseverance; for, although they were probably oppressed with sadness at leaving home and friends, with no definite prospect before them, they were sustained by their pride of consistency, and were soon carried by the current out of sight of their followers. They reached, without any incident worthy of notice, the city of Harrisburg, but here the river became so turbulent that navigation in the boat was no longer practicable, and, as their provisions were exhausted and their pockets but sparingly supplied with the means of procuring more, they sought a purchaser for the boat, and after some difficulty found one in the person of the landlord of a small German tavern, who agreed to give for it ten dollars in cash, with supper, breakfast, and a night's lodging for the party. The bargain, however, came near being cancelled on the part of the landlord, who, being a heavy man and eager to test the capacity of his purchase, imprudently stepped on the side of the boat as it floated near the wharf, and was immediately plunged beneath the surface of deep water, from which he was with difficulty saved from drowning through the assistance of the trio. Disgusted with his first essay with the boat, he declared that it was an uncertain craft, of which he would not be the owner; fortunately, however, after having recovered from his fright, and been provided by his wife with dry clothes, he concluded to stand by his engagement.

The next morning our travellers started at an early hour to accomplish the remainder of the journey on foot; and in due time, with a prudent use of the money obtained from the sale of the boat, arrived in Philadelphia. Here they separated, each to commence the battle of life for himself, with what result, except in the case of young Saxton, we are not informed.

He was provided with a letter from a friend in his native village, commending him in warm terms to a watchmaker in Chestnut Street. This person gave him employment for some time, when he left the business of watchmaking to become an engraver. In this employment he learned to draw with facility, and to sketch from nature with considerable effect. While with the watchmaker, he invented a machine for cutting the teeth of wheels, the outlines of which were true epicycloidal curves. This invention, which evinced profound thought and remarkable ingenuity, is of great value in the construction of chronometer wheels, as well as those of all other kinds of machinery.

He remained but a comparatively short time in the study of the art of engraving, and next became associated with Isaiah Lukens, a celebrated machinist of Philadelphia, who was noted in all parts of the United States for having detected the imposition in the Red-heifer machine, which had attracted much attention as a working perpetual-motion. While associated with Lukens, he constructed an astronomical clock with a compensating pendulum, and an escapement on a new plan devised by himself. This clock kept excellent time, and is, I am informed, still in good condition. He also constructed the town clock for the city of Philadelphia, which continues until the present day to proclaim the passing hours from the belfry of Independence Hall.

He acquired in Philadelphia a reputation for great ingenuity, and was elected a member of the Franklin Institute, an establishment then just commencing its careér, and which still preserves a vigorous and active existence, after having done more than any other institution for the advancement of the economical and mechanical arts in this country. In this society he became associated with Prof. Bache, G. W. Smith, Fred. Fraley, Prof. Cresson, J. V. Merrick, and a host of other young and enterprising men who have all performed important parts in the drama of life.

Impelled by a desire to enlarge his knowledge, he resolved to visit England, and for this purpose carefully hoarded his income. On his arrival in London, he placed his money in charge of a banking-house, which shortly after stopped payment, and left him amid the social solitude of an immense city of strangers, without friends, acquaintances, or the means of adequate support. He was not, however, destined to remain long in this condition. He soon made himself known at a new institution, called the Adelaide Gallery of Practical Science, an establishment founded in 1831, for the purpose of exhibiting scientific novelties, to illustrate scientific subjects, and to afford discoverers, inventors, and manufacturers an opportunity to bring before the public their works in an attractive and interesting manner. This Gallery, besides an extended series of philosophical apparatus, contained a class of objects which would afford amusement as well as instruction. Such was the Persian rope-dancer and the oriental magician, which were never-failing objects of admiration to the young as well as to the more advanced in age who were led to inquire into their ingenious and elaborate mechanism.

The first contribution which Mr. Saxton made to this institution belonged to the class we have just mentioned. It was denominated the "paradoxical head." This consisted of the figure of the head and bust of a Turk, carved with artistic skill, around the otherwise naked neck of which was a black ribbon, having what appeared to be a seam along the middle of its length. The head and the bust were apparently carved from one piece, and yet, to the surprise of the beholders, a dexterous master of fence would, after a few flourishes of a thin sword, pass the blade through the neck, apparently severing the head from the body, yet without disturbing the connection. This toy attracted great attention, and gave rise to much speculation as to the plan of its construction. By many the connection was supposed to be maintained by magnetism. This, however, was not the true explanation. The effect was produced by an ingenious arrangement of mechanism, which enabled the blade of the sword, in its passage through the neck, to unlock and lock in succession a series of catches, leaving the same connection after as before the passage of the blade.

The Adelaide Gallery was at the time one of the chief objects of interest of the British metropolis. The exhibition of the paradoxical head led to the employment of Mr. Saxton in various ways to add to the attractions of the gallery. He constructed for it a compound steel magnet which sustained the weight of 525 pounds, and also a magnetic needle of several feet in length with a mirror on its end, which exhibited for the first time by the movement of a reflected beam of light, on a magnificent scale, the daily and hourly variations of the magnetic force of the earth. He also added to the attractions of the gallery various interesting objects, such as a series of miniature vessels of various forms apparently sailing with a fair wind on the surface of an artificial lake, although impelled by ingenious contrivances of clock work in the depth of the water. He also fitted up a diving bell with glass sides in which visitors were sent to the bottom of a deep tank.

In connection with the Adelaide Gallery he soon became intimately acquainted and lived on terms of friendly intercourse with some of the most celebrated engineers and mechanicians of the day. Among these were Telford, Brunel, Whitwell, Hawkins, and others, whose names are associated with some of the proudest monuments of English engineering. Through the influence of these gentlemen, he was introduced to the meetings of the Royal Institution, and admitted into friendly relationship with the presiding genius of that establishment, the world-renowned Michael Faraday. In such association, he breathed a congenial atmosphere, his peculiar faculties being exercised to the utmost; and, stimulated by the applause of enlightened appreciation, his mind teemed with new suggestions.

For several years, about this time, he kept a diary in which he recorded daily events intermingled with suggestions which illustrated his habits, his thoughts, and his varying employment. From this record which has been placed in my hands for perusal, it is evident that he was a critical observer; that his sympathies were many sided; that he kept himself posted in the occurrences of the day, and systematically devoted a portion of time to reading the newspapers and the scientific journals of the period; that he took a lively interest in the passage of the celebrated reform bill, then under discussion; and was always alive to every item of news from America. For although he was living under the protection of a foreign government, he ever cherished an ardent attachment to the institutions of his own country; indeed his patriotism was a marked trait of his character, which evinced itself in our late civil war by the warmth of his expressions in favor of the Union. It was during the time we have mentioned that he made his great scientific invention of the magneto-electric machine. Dr. Faraday in 1831 had discovered the primary facts of electro-dynamic induction, and also those of magneto-electricity. He had shown, first, that, when two insulated conducting wires are placed near, and parallel to each other, and a current of electricity is passed through one of the wires, an induced *current will be excited for an instant in the other wire, and in an* opposite direction to the inducing current. Furthermore, at the cessation of the primary current, an induced current will take place in the same direction as the primary. These are the fundamental facts of electro-dynamics. The analogous facts of magneto-electricity are as follows: If an insulated wire be coiled into the form of a helix, and into this helix a permanent magnet be thrust, a current of electricity will circulate for an instant through the wire; while the magnet remains at rest within the coil no electrical phenomena are observed; but during the act of drawing out the magnet, an induced current in the opposite direction will be produced. The two sets of analogous phenomena fall into the same class, if we adopt the theory of Ampère, that the magnetism of a bar of steel consists of a series of currents of electricity revolving around the atoms of the magnet at right angles to its length. The existence of these currents of induction was indicated by Mr. Faraday in the motion of a delicate galvanometer. These discoveries were the intimations of the hitherto unknown action of all-pervading forces, which required clear conception, and ingenious combinations to call them forth, as it were, with palpable energy; and to do this was the task which Mr. Saxton essayed. The solution of the problem was one of great difficulty. The current or induction existed but for the fraction of a second, and in that time gradually increased from nothing up to a maximum and then declined. The problem was to exhibit this current at the period of its greatest quantity and intensity, and for this purpose it was necessary to break the closed circuit in which it moved at the critical moment, to close it again at the proper time, and so on. These requisites were admirably provided for by the simplest possible arrangements, which could only have been invented by one who had a clear and definite conception of the nature of the force to be developed and an imagination to suggest the means by which the result was to be accomplished. Success was, however, obtained by Mr. Saxton apparently without much mental effort, and the encountering of any great difficulties.

It was a part of the general principle discovered by Mr. Faraday that, if an insulated or coated wire were wound with many coils around a cylinder of soft iron, which is suddenly magnetized by touching its end with a magnet, the same effect would be produced as that described by thrusting in and drawing out a permanent magnet. A current in one direction would be excited in the coil when the core became magnetized, and a current would be produced in an opposite direction the moment the magnetism ceased. Mr. Saxton adopted for the inducing magnet to be employed in his machine, a compound one consisting of a number of steel bars bent into the form of a horseshoe, magnetized separately; and then screwed together so as to form one powerful combination. For the inducing part of the apparatus, he bent a cylindrical rod of iron of about three-fourths of an inch in diameter twice at right angles so as to produce the form of a U, the parallel legs of which were at the distance of that of the centres of the two poles of the permanent magnet. Around each of these legs he wound 30 or 40 yards of insulated copper-wire. Now it is evident from the principle before stated that when the two ends of the legs of this U of soft iron are brought in contact with the poles of the permanent magnet, an instantaneous current will be produced in the natural electricity of the wires, each in a direction opposite to the other. Again, when the soft iron U is drawn suddenly away from the poles of the permanent magnet, a reverse current will take place in each of the coils. But a more intense effect will be produced if the legs of the soft iron horseshoe or U be made to rotate before the face or poles of the permanent magnet, so as to slide off of one on to the other. In this case the effect will be double that of separating it simply from a single pole; since, if, in passing from the first pole it loses its magnetism, in passing on to the second it may be considered as being de-magnetized still further since it is changed into the opposite magnetism. A similar result will be produced with the other leg of the horseshoe. To excite, therefore, the greatest possible amount of electrical induction, Mr. Saxton fastened the U to a revolving axis passing through its crown, to which a rapid rotation could be given by means of a driving wheel and pulley. In order, however, to obtain manifestations of the induced currents produced in the copper-wire, the two ends of the coils were so soldered together, as to give a single current in one direction through the entire length of the coils. One of the remaining ends was then permanently soldered to a circular disk fastened concentrically to the revolving axis by an insulating collar, with its plane perpendicular to it. This plate dipped into a cup of mercury. The other end of the wire was soldered directly to the revolving shaft or axis. In this arrangement the insulated disk formed one pole of the long wire, and the revolving shaft the other; but as they were not connected, no electrical excitement was observed when the bobbins were revolved. To make and break the connection at the proper moment, two wires were soldered diametrically opposite each other on a ferule which fitted tightly with friction on the revolving shaft. These wires standing out at right angles to the shaft were cut off at such a length, that at each revolution, the ends would plunge into the same cup of mercury with the revolving disk, and thus complete and break the circuit twice with each revolution of the bobbins. These wire points were then so adjusted by turning the ferule on the shaft as to cause them to enter and leave the mercury at the moment when the magnetism was increasing or diminishing most rapidly, and consequently when the current had the greatest intensity.

With this instrument he was enabled to exhibit a brilliant electrical spark, to decompose water, to show the electrical light between charcoal points, and to give a rapid series of intense shocks. The instrument was exhibited to the public for the first time at the meeting of the British Association at Cambridge in June, 1833, where it excited much interest, and was permanently placed in the Adelaide Gallery in August of the same year. The poet Coleridge, who was present at its exhibition in Cambridge, spoke with enthusiasm, not only of the magnitude of the discovery of the inductive electrical effects of magnetism, one of the claims of Faraday—to imperishable reputation—but also of the ingenious invention of Mr. Saxton, by which the transient electrical currents might exhibit their effects in so brilliant and so powerful a manner.

Strange to say, however, no description of this instrument was published in any journal until 1836. In the August number of the *London and Edinburgh Philosophical Magazine* of that year, an instrument-maker in London by the name of Clarke published an account of a machine identical in principle with that invented by Mr. Saxton, differing from it only in a few unessential arrangements of parts—affording one of the most signal instances of unblushing piracy on record.

Saxton's reclamation was published in the October number of the same journal, and is a dignified and convincing exposition of the wrong to which he had been subjected. It is, with the exception of the description of the instrument, given in full in the following extract from the journal before mentioned:—

"I regret that I am called upon to notice a very disingenuous article in the number of the *Philosophical Magazine* for October. A reader, unacquainted with the progress which magneto-electricity has made since this new path of science was opened by the beautiful and unexpected discoveries of Faraday, might be misled, from the paper I have alluded to, to believe that the electro-magnetic machine there represented was the invention of the writer; and that the experiments there mentioned were for the first time made by its means. No conclusion, however, would be more erroneous. The machine which Mr. Clarke calls *his* invention differs from mine only in a slight variation in the situation of its parts; and is in no respect superior to it. The experiments, which he states in such a manner as to insinuate that they are capable of being made only by his machine, have every one been long since performed with my instrument; and Mr. Clarke has had every opportunity of knowing the truth of this statement.

"Though my machine is well known to the public from its constant exhibition at the Adelaide Street Gallery since August, 1833, and my claims as its inventor have been acknowledged by Professors Faraday, Daniell, and Wheatstone in papers of theirs published in the *Philosophical Transactions*, yet, as no description of it has yet been published, I will thank you to insert the following in the ensuing number of the *Philosophical Magazine.*"

After giving an account of his machine, he concludes as follows:—

"In conclusion, I think it will be evident, from the preceding statement, that the magneto-electrical machine, which Mr. Clarke has brought forward 'after much anxious thought, labor, and expense,' is a piracy of mine; the piracy consisting not in manufacturing the instrument—for every one is at full liberty to do so—but in calling it an invention of his own, and suppressing all mention of my name as connected with it."

This reclamation, however convincing, was too late to prevent the introduction of the name of Clarke as the inventor of the magneto-electrical machine in the continental journals; and even in the extended history of electricity by Becquerel, the credit is given to the same person.

During Mr. Saxton's residence in London, he also invented the locomotive differential pulley, a description of which, and the method of producing rapid and uninterrupted travelling by means of a succession of such pulleys by horse power, was given by Mr. John J. Hawkins to the British Association, at its third meeting, held in Cambridge, in 1833. The fundamental principle of this may be understood by supposing motion to be given by a cord to a pulley, say six inches in diameter, around the axis of a wheel of six feet in diameter. It is evident, then, that if motion be given to the smaller pulley by unwinding the rope, the larger wheels will move with a velocity of twelve times that of the smaller wheels, or, in other words, with twelve times the velocity of the impelling rope, and give an equal velocity to another rope to which carriages may be attached. Mr. Hawkins concluded from his calculation that a continuous motion of thirty miles an hour could be given to a passenger coach by relays of horses, walking at the rate of two and a half miles an hour. A company was formed for the application of this invention on canals, but owing to the great success of steam locomotion the project was abandoned. It may, however, be yet applied in elevated railways, and under conditions in which the immediate application of steam power cannot be made.

Mr. Saxton also invented an apparatus for measuring the velocity of vessels, which was applied with a dynamometer for determining the resistance of vessels on a canal with different velocities.

It appears from his diary that at one time he had the principal charge of the apparatus of the Adelaide Gallery, and this gave him an opportunity of making observations and experiments of interest. He states that on firing a volley of lead balls from a Perkins steam gun, which was one of the objects on exhibition, against an iron target, a glow in the dark was observed of a nebulous appearance, each ball as it struck the iron emitting a flash of light. He experimented with the apparatus for condensing carbonic acid and for its use in the propulsion of balls; the result, however, did not answer his expectations. Too much of the elastic power of the substance, he says, was expended in moving itself to give the ball a comparatively great velocity. He also made experiments with the apparatus invented by Mr. Perkins for exhibiting the compressibility of water. This consisted of a strong cast-iron bottle into the neck of which a cylindrical plunger was carefully fitted, and this was forced down into the vessel when filled with water by means of a hydrostatic press. The degree of compressibility of the water was indicated by a ring on the plunger which being pushed up by the descent of the plunger retained its position by friction, and thus indicated the depth to which the rod had been projected into the water. The result of the experiments gave a much greater ratio of compressibility than was afterwards obtained by Oersted of Copenhagen.

The difference was probably due to the fact that under the great pressure to which the apparatus was subjected, a portion of the water was forced into the pores of the iron, and thereby, as it were, increased the capacity of the vessel. This explanation is rendered the more probable from an experiment made by Mr. Saxton himself, which consisted in filling a small ball of brass with thick sides, entirely with water, secured by a screw tap. This, being subjected to a temperature below freezing during a cold night, was found in the morning covered with minute filaments of ice which the expansion of the water had forced through the pores of the metal.

Mr. Saxton during his life was fond of rural sports. He was a very successful angler, and early excited the admiration of his companions by the invention of a simple instrument by which he could project his line into the middle of a rapid river, while standing on its bank. For this purpose he cut a shingle or thin board into the form of a fish, loaded one edge so that it would float vertically; from the lower edge of this he suspended lines with baited hooks; to one of the flat sides of this fish he applied three cords united in one long string, after the manner of the cords of a kite. When this instrument was thrown into the water, and the fisherman on the bank, holding the end of the long string, ran a short distance up the stream, the artificial fish would move off into the middle of the river and there remain, for the same reason that a kite ascends in the air and remains at a high altitude, under similar conditions of pressure and equilibrium.

He also amused himself with hunting, but even in this the pleasure was more in the exercise of his inventive faculties than in the gratification of the remnant of the brutal propensities which induces civilized man to the wanton destruction of animal life.

The use of ordinary instruments was not sufficient for the gratification of his tastes. He was in the habit of employing an air-gun of which the reservoir, syringe, and barrel were formed of the several parts of an ordinary sized walking cane. In the use of this instrument he was extremely expert, and could discharge a number of balls in succession through a mark on an inch board at several rods distance. He also attached a small telescope to his rifle, adjusting its axis to that of the bore, so as to insure the hitting of the target at a great distance when the cross hairs in the focus of the telescope apparently cut the bull's eye. For the use of this gun he invented what has since been a source of great emolument to the owner of a patent right: I allude to the metallic cartridge now so generally used, especially in the art of war.

In the diary which we have previously mentioned, there are accounts of various inventions which had suggested themselves to him during the mental stimulus of his life in London. Among these are the method of indicating the height of water within a steam boiler, which consisted in placing a floating hollow magnet in a copper tube; communicating at one end with the top, and at the other with the bottom of the boiler. Surrounding this tube was another of glass also containing water in which a second magnet floated, the position of which marked the height of water in the boiler. An invention similar to this has since been patented and brought into use.

Another invention was that of a fountain *pen*, which, in practice, fully realized his anticipations; another, an ever-pointed pencil, which was among the first of the various forms of this instrument of expressing thought which have since been adopted. Although his mind was more directed to the application of scientific principles than to original investigation, yet under different conditions of life and of early mental training, he would undoubtedly have excelled in this line. Besides the experiments we have already mentioned, he records a series of experiments in relation to the lateral adhesion of a current of water projected through a reservoir of the liquid, and finds in one experiment, that fourteen times as much water was thrown out of a shallow basin as was projected into it through the nozzle of a syringe, obliquely inserted under the surface.

He also gives a method of determining the position of the interior magnetic poles of the earth, by projecting, in the form of a large circle, a section of the earth through the magnetic meridian. On the circumference of this drawing, he next projected the dip of the needle in different latitudes from the equator to the pole, and by prolonging these projections until they meet in the interior of the earth, determining the position of the centres of magnetic influence in the two hemispheres. By this process, he arrived at the conclusion that the magnetic polarity of the earth is deeply seated in the interior, and that consequently the magnetism of the globe may be represented by a comparatively short magnet, the axis of which passes through the centre of the globe. A result similar to this was afterwards arrived at by a series of mathematical investigations by the celebrated Poisson. He also made a drawing of an arrangement of apparatus for obtaining an electrical spark from the magnetism of the earth. This consists in the rapid revolution of a large bar of soft iron on a horizontal axis at right angles to its length in the plane of the meridian, the bar being surrounded with a very long wire, insulated with a covering of silk; an arrangement being made to break the circuit at the instant of the bar receiving the greatest amount of magnetic induction. He succeeded by this arrangement in producing currents of electricity of considerable power, but for the want of a sufficient length, at the time, of insulated wire, he was unable to increase the intensity sufficiently to produce the spark, but that the result intended to be arrived at could be produced in this way there is no cause for doubt, provided the apparatus is constructed on a sufficient scale of magnitude.

I should have mentioned that Mr. Saxton constructed the apparatus by which Prof. Wheatstone made his celebrated experiment of measuring the velocity of electricity in its passage through a long wire. In this experiment the remarkable fact was discovered that in the discharge of a Leyden jar through a long wire the disturbance, whatever may be its nature, takes time for its propagation, and arrives last at the middle of the length of the conductor. On the cause of this phenomenon Mr. Saxton has some ingenious reflections.

While in London Mr. Saxton was elected a member of an experimental society, composed of men of scientific skill and mechanical ingenuity. It met once a week for the purpose of investigating certain classes of phenomena which did not require complex apparatus or long-continued observation. As an illustration of the character of this society, which might be adopted with advantage at the present day, I may be permitted to give an account of an investigation which it made of a phenomenon described by Sir D. Brewster in his work on Natural Magic, and which was said to have been exhibited in Italy by an officer in the American Navy. A man is laid on a table, face upward, with his arms crossed over his breast, and his whole body kept by sustained volition in a rigid condition; six other men then arrange themselves, three on each side, at nearly equal distances apart, so that two stand opposite each other at the shoulders, two opposite each other at the middle of the body, and the two others at the knees. Each of these then projecting the forefinger of each hand place it a little way under the body, and at a given signal, all, including the man on the table, inhale as full an inspiration of air as possible, and at another signal instantaneously and slowly breathe out the air over the recumbent subject, at the same time lifting gently, when the body will, according to the account, rise apparently without effort on the part of the lifters, and remain suspended for an instant on the ends of the fingers until the expiration of the air is completed. In the investigation of this phenomenon, as in that of all others, a director of the investigation was appointed whose instructions were implicitly followed. At the conclusion of a series of experiments the results were discussed, and any omissions that might have been observed were considered. If these were important the experiments were repeated, and so on until every doubt was removed, and unanimity of opinion obtained. In the case in question every member of the Society was at one time or another the load or a lifter, and particularly the heaviest and the lightest members were in succession placed upon the table. At the first trial some surprise was expressed at the apparently little effort required to elevate the body, and with the aid of a little imagination, persons not accustomed to scientific investigation might have thought that there was something mysterious in the result. But after full discussion it was concluded that the effect observed was due to the tension of the muscles of the body, the simultaneous effort of the lifters, and, above all, to the fact that the weight of an ordinary sized man, of say 150 pounds, when divided among six persons, or rather among twelve hands, would give to each hand only a little more than twelve pounds. But to bring this explanation to the test of experiment, a spring balance was attached to each forefinger of the lifters, and the amount of force thus exhibited being noted, the sum of the forces exerted was found exactly equal to that of the weight of the body lifted. The feat of supporting the weight of the smallest member after it had been elevated, for any length of time, upon the forefingers of six persons was found impossible.

In this Society Mr. Saxton, by his ingenuity in devising experiments, and his dexterity and skill of manipulation, was an active and important member.

He left London on the 1st of May, 1837, on his return to America, having been offered by Dr. Patterson, Director of the United States Mint in Philadelphia, the office of the constructor and curator of the standard weighing apparatus of that establishment. Previous to this, however, he had been tendered the office of director of the printing machinery of the Bank of England, but from undiminished attachment to his native country, notwithstanding nine years of absence, he declined the flattering proposition.

On the eve of his departure a farewell dinner was given him at the Piazzi Coffee House, at which were present some of the most prominent engineers and savants of the city. At the close of the banquet a work on mechanics was presented to him, by the editor, Jno. Isaac Hawkins, on the fly-leaf of which was the following inscription :—

"Presented April 26, 1837, by the Editor, to Joseph Saxton, Esq., of Philadelphia, at a farewell dinner given to him in London, previous to his departure for America, by eighteen of his friends, as a token of the high estimation in which they hold him as a mechanician of the first rank, and a man of science generally; in which estimation his fellow-citizen, the Editor, stands second to no one."

As a further illustration of the estimation in which he was held, I may quote, from a scientific journal[1] published at the time in London, the following extract :—

"Mr. Saxton, of Philadelphia, now in London, who is justly celebrated for his acute feeling in regard to the nature and value of accuracy in mechanism, and who is reputed not to be excelled by any man in Europe or America for exquisite nicety of workmanship, has made an instrument for cutting the teeth of watch wheels truly epicycloidal. Such an instrument ought to be in the hands of every engineer."

While in London, Mr. Saxton perfected the medal-ruling machine; an apparatus for tracing lines on metal or glass, at a minute distance from each other, which shall represent by an engraving the design on the face of the medal. A machine of this kind was invented in 1817 by Mr. Gobrecht, of the U. S. Mint, and applied to the engraving of medals. This was but the first step in the invention, the machine being applicable only to medals of low relief. It is not difficult to imagine an arrangement of machinery such that, while a blunt point, fastened at one end to a movable beam, in tracing a line across the face of a medal, rising and falling, according to the elevations and depressions over which it passes, another point connected with the same beam, shall draw a profile of this line on a flat surface. The simplest mode of effecting this would be that of placing the surface to be engraved at right angles to the plane of the medal. But the same can be effected, where the two surfaces are in one or in parallel planes, by a series of levers, which will convert the vertical into a horizontal motion. If now the tracer be made to

[1] Magazine of Popular Science, London, 1836.

move successively in a series of parallel lines at equal, minute distances over the whole surface of the medal, and at the same time the vertical motion is converted into one at right angles on the plate, a series of profiles will be engraved which together will form a picture of the medal. In this instrument, when the tracing point passes across any part of the medal in a straight line, a similar straight line will be etched or cut upon the plate; but when the tracing point rises above the base of the medal, the etching point will deviate from a straight line by a distance either equal to or proportional to the elevation. Two consequences follow from this effect. First, when the profiles of two consecutive lines passed over by the tracer are drawn on the plate, the more the second line rises above the first, the closer will the second line approach the first, and *vice versa*. Hence, the etching of that part of the medal along which the tracing point ascends in its successive passages will have its lines closer together; and that of the part along which the tracing point descends will have its lines further apart than those lines produced by the flat parts of the medal; and these crowdings and separatings of lines will produce shadings exhibiting a picture of the medal. But a second consequence of this arrangement is, that points which are in the same cross section of the medal are not represented in the corresponding cross line of the plate, but deviate from it in proportion as the path of the tracer is higher or lower. This gives rise to a distortion of the features, changing, for example, the relative position of the eye and the ear. This effect, though not very perceptible in copies of medals in low relief, becomes very objectionable in those of high relief. This defect, which was inherent in Mr. Gobrecht's instrument, was entirely remedied by Mr. Saxton. His improvement consisted in an ingenious contrivance by which the etching point was made to move over a distance equal to the horizontal projection of the tracing point in its up and down movements as it passes over the surface of the medal. For this purpose, the up or down movement of the tracing point must be to the movement of the etching point as the hypothenuse of a right-angled triangle to its base. And, furthermore, to effect this, he caused the tracing style to be inclined at an oblique angle to the plane of the plate, usually that of 45°. By these changes, requiring inventive powers of a high order, he removed entirely the distortion, and rendered the ruling-machine capable of engraving fac similes of medals, as well of high as of low relief. He subsequently rendered the apparatus entirely automatic by applying to it the motive power of water or steam, so that when once set in motion it would faithfully perform its task with unerring precision; and, when the ruling was completed, it would stop on the instant, cutting off the motive power. The rapidity of the execution was another feature of the apparatus; one face of a coin, an inch in diameter, ruled with lines the one two-hundredths of an inch apart, was completely engraved in about half an hour. The importance of this machine may be inferred from the fact that a new book of coins seems to be required by the commercial world about once in twenty years; and such a work is of comparatively little value unless fully illustrated by reliable engravings. A very interesting work prepared by Mr. Jacob R. Eckfeldt and William Du Bois, of the United States Mint, entitled "A Manual of Gold and Silver Coins of all Nations struck within the last Century," was published in 1842, and admirably illustrated by numerous engravings primarily executed by the apparatus we have just described. This work, which is well known to the professed numismatologist, should be in the hands of every one who desires to become acquainted with this branch of historic records. It is dedicated to Robert M. Patterson, M.D., Director of the Mint, and Vice-President of the Philosophical Society; a gentleman who was no less remarkable for his varied and profound scientific acquirements than for kindness of heart and urbanity of deportment. He was a warm admirer and ardent friend of our lamented associate; and it was he who, as we have said before, recalled Mr. Saxton from London and gave him the position of balance-maker to the Mint of the United States.

Dr. Patterson was fond of exhibiting and explaining Saxton's ruling machine to the distinguished visitors of the mint. It was, indeed, an interesting exhibition to see this machine engraving its fine lines, moving its tracer backward and forward, without the aid, or even the observation, of a superintendent, and stopping when its task was accomplished, and, by the sound of a bell, calling for more work.

"I recollect," says a friend, when the President of the United States and his cabinet were making a visit to the mint, the pleasure manifested by Dr. Patterson in showing the machine in operation. They all appeared deeply interested in the exhibition, with the exception of the Secretary of the Treasury, who, when told that it was not making, but copying coins, turned upon his heels without giving it further attention, disappointed, it would seem, in its not being able to contribute to the material of his department."

Mr. Saxton constructed during his connection with the mint, the large standard balances still used in the annual inspection of the assays and the verification of the standard weights for all the government assay and coining offices in the United States. The knife edges of these implements are of the hardest steel, turning upon plates of agate, and such sensibility has the apparatus, that when loaded with fifty pounds it turns with one-tenth of a grain, or, in other words, with the three-millionth part of its load.

Mr. Saxton was elected a member of the American Philosophical Society in 1837, and renewed his association with the Franklin Institute. In November, 1834, he was awarded the Scott legacy medal of the latter establishment, for the invention of a reflecting pyrometer, in regard to which the following is the report of the committee to which the invention was referred.

"This instrument shows and measures, in a peculiar and advantageous manner, the linear expansion of a metallic or other rod subjected to the influence of heat. The rod resting against a fixed support at one end, the other end of it presses against a sliding bar, which carries an arm attached to one end of a fusee chain of a watch. This chain is wound around an axle carrying a mirror; and the other end of the chain is fastened to a spring, to preserve its tension. Hence as the rod under trial expands, and the sliding bar moves, the axle and mirror revolve, and if a sunbeam thrown upon this mirror in a proper position, be reflected from it upon a distant wall, the angular motion of the reflected image will be twice that of the axle; and will serve to measure the amount of expansion. As the sun is also in motion, a fixed mirror near the revolving one is made to reflect another beam, at first coinciding with the former one; and as the latter beam moves only with the sun, the angular distance between the two reflected beams or images will be twice the angular motion of the axle. This instrument is especially valuable for the trial of compensating pendulums, as has been proved by Mr. Saxton.

For this purpose, the pendulum was inclosed in a hollow cylinder, in order that hot or cold water might be used for varying the temperature, the cylinder was supported vertically in a proper wooden frame; and the lower end of the pendulum, passing through a cock tightly closing the lower end of the cylinder, was adjusted to the sliding bar beneath it, which pressed firmly upward against the pendulum by the action of a spring. By this arrangement the revolving mirror was found always to return to its first position, when slightly moved by the hand; thus showing the delicacy of the mechanism, and the pendulum was considered perfect when a change of its temperature caused no motion of the revolving mirror.

"The Committee deem this invention of Mr. Saxton's so useful and ingenious that they recommend the award of a Scott's legacy medal as a slight recognition of his service in the cause of science and the useful arts."

Professor Mayer of Stevens Institute, one of our fellow-members, informs me that he used Mr. Saxton's comparator in an elaborate research on the effects of magnetism in changing the dimensions of iron, and found it to exceed in minute precision all other instruments, indicating changes in the length of a bar to the $\frac{1}{100000}$th part of an inch.

On the death of Mr. Hassler, superintendent of the Coast Survey, in Nov. 1843, Prof. Alex. Dallas Bache was called to fill the important sphere of duty thus rendered vacant. The office included also the superintendence of the weights and measures of the Government, and immediately after his appointment he tendered to his friend Mr. Saxton the charge of the construction of the standard balances, weights, and measures to be presented to each of the States for insuring uniformity of measures in all parts of the country. Mr. Saxton accepted this position, and immediately removed to Washington, where he was destined to spend the remainder of his days. His labors, however, were not confined in this new position to the construction of the weights and measures, but were extended to the construction of different portions of the complex apparatus employed in the varied and multiform operations of the Coast Survey. In this connection he invented an automatic instrument for recording the height of the tides, corresponding to the different hours of the day. He also applied his reflecting pyrometer to the construction of measuring rods which would retain their unvarying length while subjected to different temperatures. These rods were used with great success in measuring the base lines and lines of verification of the survey, an operation which was performed with such accuracy with the aid of Mr. Saxton's improvements that with repeated measurements under different temperatures in a distance of five miles, a difference would be found not to exceed one-half inch.

Among other improvements made by Mr. Saxton in the apparatus used by the Coast Survey, was that of rendering automatic the large dividing machine for graduating the limbs of angular instruments. By this improvement the heat of the body was removed, and all irregularity occasioned by personal peculiarities, such as tremor of hand, defect of vision, etc., was obviated. The drawings of the proposed improvement were made by Mr. Saxton and the work executed by Mr. Wurdemann, the mechanician of the Coast Survey. The machinery is too complicated to be understood without a drawing. The power to give motion to the apparatus was drawn from the water supply of the building, and applied directly to a small turbine wheel of a few inches in diameter, the induction tube of which, connected with the supply pipe of the house, was of India rubber of about three-quarters of an inch in diameter ; the eduction tube was of the same material and of the same diameter, passing down through the floor, discharging the water into the drain beneath the house. By this arrangement, though the motive power was water, yet none of the liquid was observed in the room in which the apparatus was situated. The work required to be done by this turbine wheel, the power of which was transmitted by a pulley and cord to a large wheel turning an axis tangent to the large divided circle, was first to move this circle through one division and with it through an equal angular space, the smaller circle which was to be divided. The large circle stopped at this point until a small lever bearing the marker on one of its ends rose above the circle to be divided, moved to its outer circumference, then toward the centre of the circle across the limb, making a permanent cut, then stopping and remaining stationary until the two circles had made another movement equal to a given division, and the above mentioned process repeated. These automatic movements were effected by an arrangement of cams which converted the rotatory into horizontal and vertical motions. The effect on the observer was that of a series of movements produced by human volition. The results, however, were very different, since, however admirably adapted the human machine may be to execute the intentions of the will, yet the will itself is inconstant, the attention soon becomes fatigued, and the application of thought to one unvaried process of acts soon becomes unsteady. In the case of the machine, however, there was no effect analogous to fatigue, no thought was required to direct at every instant the motion, and the pen or marker at the extreme point, impelled by a train of mechanism, pursued unchangeably its predestined course.

At the meeting of the American Association in Baltimore in 1858, Mr. Saxton gave an account of the principal applications which he had made of the revolving mirror to minute measurements in addition to the pyrometer previously described. In the application of this principle to the adjustment of the measuring rods of the Coast Survey, and for minute measurements, he had applied, instead of a sunbeam, a graduated scale, the reflection of which entered the object glass of a telescope and was then observed highly magnified. With this improvement an elongation which does not exceed the one hundred thousandth part of an inch becomes a very distinct and measurable magnitude. The same apparatus was applied at the request of Capt. (now General) Meigs to determine the expansion of different specimens of marble cut into prisms of the same length and cross section, to ascertain the relative thermal expansion. The same principle is evidently applicable to all cases where the measure of changes of length or of angle or position is required. It was applied by Mr. Saxton in the Girard College Magnetic Observatory, to indicate changes of magnetic dip and also to magnify the motion of the axis of an aneroid barometer. For this latter purpose the case of the instrument is removed and a mirror of about one-half an inch square is attached to the first axis of motion. The aneroid thus furnished is fastened to a bracket on the wall with the axis to which the mirror is attached placed horizontally. At the distance of about fifteen feet from the mirror a telescope is permanently adjusted, so that the image of a divided scale placed immediately below the object glass can be seen in the mirror. With this arrangement, the slightest change in the pressure of the air became apparent. The opening or closing of a door, or a gust of wind over the house, produced marked disturbances in the pressure of the atmospheric column, the extent of which could be readily measured.

The application by Gauss of the mirror to a magnetic bar to magnify its angular variation was subsequent to its first use for a similar purpose by Mr. Saxton. The first application by our associate, of the principle of the turning mirror to magnify angular motion was as early as 1825. One of his modifications of the revolving mirror consisted in fastening obliquely to a revolving axis, a small mirror on which, if a ray of light was thrown from any source and when a sufficient velocity was given to the mirror, a large circle of light would be projected on a prepared screen or on the ceiling of a room. A rapid revolution was given to the axis by a train of wheels driven by a coiled spring, and with this instrument rapid fluctuations in the intensity of a light could readily be observed. When the ray of light was from charcoal points, forming the poles of a galvanic battery, the circle of light exhibited a mottled or dotted appearance, indicating a rapid alternation of intensity in the electrical discharge.

Among the inventions which he made after his return to America, was that of a stove for burning anthracite coal. In this, the draft was regulated by the different expansion of two metals, by which a valve was opened or closed to the required extent for preserving the stove at a given equable temperature, which could be regulated in advance.

Another invention was that of a method of sealing official papers by means of a fusible metal, obviating the necessity of the use of wax, which is found to melt in passing through the mail in warm countries. The same contrivance is used for fastening trade marks on goods.

He also made a hydrometer, by which the quantity of spirits in a mixture was immediately indicated by the number of links of a fine chain, hanging from the lower part of a floating bulb, and partly resting on the bottom of the vessel. When the strength of the liquor was diminished by the addition of water, the bulb would float higher, drawing up from the bottom an additional number of links, until the equilibrium was again obtained.

It would appear from the facts relative to the life of Mr. Saxton, that he devoted himself to invention more from the mental pleasure which he derived from this exercise of his imagination, than from any desire for scientific reputation or for pecuniary gain. We have seen that he published no account of his magneto-electrical machine until he was called upon to defend his claim to the invention, though it was publicly exhibited in the Adelaide Gallery for months, and had excited the admiration of the many visitors to that establishment; and that although several of his inventions were patented in London, this was through the influence of others, who desired to share in the profits, rather than by his own act. Had he secured the exclusive right to manufacture the metallic cartridges, of which he was undoubtedly the first inventor, he might have acquired wealth sufficient to realize the dreams of avarice. The pleasure of exercising his inventive powers, and the gratification of employing the products of his ingenuity, were enough for him; and with the characteristic of unselfish genius, he left to others to gather the golden apples which he strewed along his path.

Mr. Saxton was not a mere practical man in the ordinary sense of the term—that is, one who by repetition and empirical imitation, becomes expert in the performance of operations devised by others, and has no knowledge of principles. On the contrary, he had clear and definite conceptions of the scientific elements of physical energy in its multiform manifestations, and, with an ever-teeming imagination applied them with success. He was singularly free from unconditioned speculations, and although he possessed an imagination of great fertility, it was always under the control of a discriminating judgment which confined its operation to the region of the tangible and the actual.

Such was his habit in the exercise of his invention that he could scarcely be prevailed upon to reduce to practice the conceptions of others, or if at any time in the course of his official duties he was called upon to perform a work of this kind, it was always executed with modifications of his own.

Mr. Saxton was at no period of his life a profound student of science. He possessed more wisdom than learning; after having obtained a clear and distinct conception of a general principle he reflected deeply on this, deduced logical consequences from it; imagined new conditions, and inferred new results. I doubt whether at school he was considered a bright youth, possessing the faculty of rapid acquisition. This faculty and that of original conception are not always found in the same individual; so far from this being the case, the contrary is the rule and the other the exception. No amount of drilling can make, for example, a first-class engineer if the proper constitution of mind be wanting. A pupil may in after life disappoint the expectations of his friends on account of the promise founded on an aptitude for acquiring expertness in mental operations and a knowledge of rules, without a definite conception of principles.

Mr. Saxton, in person, was considerably above the ordinary height, and admirably proportioned. He had a broad and high forehead, a countenance marked by thought and benevolence. He delighted, as we have said, in hunting and fishing, and in making excursions on the water or in the woods in the vicinity of Washington. While he was thus exercising his body, his mind was actively employed; nothing appeared to escape his attention. He made a large collection of pre-historic implements to be found in the vicinity of Washington, and collected specimens of the geology and mineralogy of the District of Columbia. He was of singularly modest deportment, and only in the company of a few persons, and those his intimate acquaintances, did he give indications of his intellectual powers.

In 1850 Mr. Saxton married Miss Mary H. Abercrombie, the granddaughter of a well-known Episcopal clergyman of Philadelphia, and although there existed between himself and his wife a considerable disparity of age, the union was a fortunate one. His wife sympathized in his pursuits and affectionately administered to his wants in his declining health. The issue of this union was a daughter, now the wife of Lieut. Pendleton of the U. S. Navy.

Within a few hours of the death of our associate his daughter gave birth to a son, who having received the name of Joseph Saxton, we may hope that he possesses the germs of the mental and moral peculiarities of his grandsire, and will thus not only transmit his name to posterity, but also peculiarities which will affect for good coming generations.

About fifteen years before his death he was suddenly seized with a partial paralysis from which he never entirely recovered. Another attack followed about ten years later, and after lingering for two years or more, his power of utterance gradually diminishing, he became incapable of articulation, and finally, before breathing his last, became unable to hold communication with the external world. His end, however, was peaceful, and he received from his affectionate wife and daughter all the vigilant care and tender sympathy which fervent devotion could contribute.

I trust, in what I have narrated relative to the life and labor of our deceased companion, that he will be deemed worthy of having been a member of the National Academy of Sciences.