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MEMORIAL

OF

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DISCOURSE MEMORIAL:*

BY

REV. SAMUEL BAYARD DOD.

"I have written unto you, young men, because ye are strong, and the word of God abideth in you."—I JOHN ii. 14.

THE beloved Apostle, in giving unto each class of his readers a word in season, uses the language of our text in addressing the young men, pointing them to the abiding of the word of God in their hearts as furnishing the necessary elements for the formation of a strong character. I shall try to point out to you how the word of God meets the necessities of human character in the period of youth, and what special value it has for the young, in correcting the errors incident to that period of life, and in supplying the elements needed for the formation and fixing of character.

Perhaps no one thing contributes more to retard the growth and permanent progress of our character than the changes and fluctuations of feeling through which we are continually passing.

The mere progress of life, by enlarging our views and bringing us into new associations, works a great change in our feelings. The mountains of our youth are but hills in the eye of manhood; its palaces are transformed into plain houses; its suns dwindle into stars; its visions splendid "fade into the light of common day;" its ardent and generous impulses are tamed into a cool worldly wisdom.

Beside this more general and permanent change, there are fleeting clouds of feeling, quick changes of sunshine and shadow continually passing over us. What alternations of hope, fear, anxiety, joy, melancholy we pass through in a single week! How, with each aspect of the mind, the outer world seems changed, according to the medium through which we view it.

*This Sermon, delivered in the College Chapel, PRINCETON, N. J., on the 19th of May, 1878, (the Sunday following Professor HENRY'S death,) was published in the "Princeton Memorial."

How then amid all this change, shall the heart be kept in one steady, consistent course of progress, and not be at the mercy of transient states of feeling? Are there not passages of your own experience that verify this description? I do not speak of that ordinary experience exposed to the view of the world in your actions, but of that inner life, which you keep hidden from the world's gaze.

Of what does that testify? Of struggles between opposing desires; of broken vows and resolutions; of calm views suddenly overcast with dark clouds; of elevated aims dragged down to the mire and dust; of fitful seasons of repentance and self-humiliation. Our own inner experience reveals purposes formed far higher than we have ever embodied in action—an ideal life which has little influence on our real life, which consists mainly in unhappy grasping after a higher life, but which is only realized in the dreams of our imagination.

To counteract this tendency we must learn to act on some fixed principle. We must choose some great purpose for which we will live, great enough to be a controlling influence over all our life, which we can set as our pole-star in the heavens. Such a purpose, and influence, is furnished by the word of God.

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But we rest the argument for this truth not only upon what we may infer the influence of the abiding of the word of God in the heart to be, but also upon the experience of our fellow-men who have made that word the guide of their lives.

There passed away from among us, on Monday last, one whose life and labors beautifully illustrate this truth. It is meet that within the precincts of this college, special mention should be made, in terms of reverent affection, of Professor JOSEPH HENRY.

We claim him as one of us—not a son of Princeton, it is true, for in a far humbler academy his early studies were prosecuted; but we claim him as a brother, beloved and loving, for he loved Princeton sincerely. From her he received his title of Professor; in her old Hall of Natural Philosophy he prosecuted his researches, begun in Albany; among her professors he found kindred spirits whom he honored and loved; to her students he delighted to impart the fruits of his study, and kindle in them some of the earnest enthusiasm which marked his pursuit of knowledge. And, when a call which he regarded as imperative, carried him away from here, he retained his place still among her professors, and often revisited Princeton; and those who knew him well, remember his constant expression of regret and of longing for this peaceful academic life, with its opportunity for research.

As we look at the appliances of a physical laboratory in these days, and remember the meagre apparatus of forty years ago, we wonder at the genius and patience of this great discoverer, who with limited means, devised and in great measure constructed the apparatus with which many of his wonderful discoveries were made.

I presume that you are familiar with the few incidents of his life. With no advantages in the way of early education, with limited means, with no patronage of friends to aid him, by his own labor he earned his livelihood, by his own efforts he obtained recognition and position. First called at his graduation, to the chair of Mathematics in the Albany Academy, from there he was called, in 1832, to the professorship in Princeton, and from there, in 1846, to the Smithsonian Institution at Washington.

This is not the time nor the place to enter into a detailed account of those discoveries, begun in Albany and carried on here, which have given him not only a national, but a world-wide fame. I shall only attempt to point out some of those characteristics which distinguished Professor HENRY as a philosopher and as a man.

As a student of science he was ardent and enthusiastic in his love for the chosen pursuit of his life. He did not dally with it as a pastime, nor prosecute it with the greed of gain, nor pursue it with the ambition of making himself famous among men. He desired knowledge, and searched out wisdom in the love of it. One of his students says, speaking of his construction of his second and largest magnet: "We shall always remember the intense eagerness with which he superintended and watched his preparations, and how he fairly leaped from the floor in excitement when he saw his instrument suspending and holding a weight of more than a ton and a half." Another writer, speaking of his examination of the telephone at Philadelphia, says: "It was a most lovely sight, at the Grand Exhibition at Philadelphia, when Professor HENRY, the father of the system" of electro-magnetic communication, "and Sir WILLIAM THOMPSON, the greatest living electrician in Europe, met and experimented with that mysterious telephone. Their pleasure reminded me more than anything else of the exuberant joy of childhood, when some beautiful revelation of nature has been for the first time brought to its brain, and when the innocent child expresses happiness in every feature of its face and every movement of its person."

He was characterized by great reverence in the pursuit of truth. Singularly modest as to his own powers and attainments, he never suffered the advancement of his own opinions to warp his judgment or govern his investigations; he held the progress of truth dearer than the success of a theory. And nothing moved his gentle nature to greater indignation than the pretensions of the charlatan or bigot in science.

In all his researches he was actuated principally by the desire to make the results of his study of benefit to his fellow-men. His own noble words sum up the ruling principles of his life as a scientific man. He says, when put on trial for his character as a man of science and a man of honor, "My life has been principally devoted to science and my investigations in different branches of physics have given me some reputation in the line of original discovery. I have sought however no patent for inventions and solicited no remuneration for my labors, but have freely given their results to the world; expecting only in return to enjoy the consciousness of having added by my investigations to the sum of human knowledge. The only reward I ever expected was the consciousness of advancing science, the pleasure of discovering new truths, and the scientific reputation to which these labors would entitle me." And verily I say unto you, he hath his reward.

As an investigator, Professor HENRY was characterized by great patience and thoroughness in his work of observation, and by broad, well-considered, and far-reaching generalizations. He distrusted the so-called "brilliant generalizations" with which those favor us who love speculation rather than study. He never took anything for granted, never despised the details of his work, but carefully established, step by step, those data on which he based his conclusions. In 1849 he says, "Since my removal to Princeton I have made several thousand original investigations on electricity, magnetism, and electro-magnetism, bearing on practical applications of electricity, brief minutes of which fill several hundred folio pages. They have cost me years of labor and much expense."

Combined with this thoroughness, there was great fertility of mind. He was distinguished not in one branch of physics, but in all. In the catalogue of his published papers (and these represent but a small part of his work, for he worked much and published comparatively little) there is evidence of the varied fields in which he wrought. While a large part of them are devoted to his favorite and most famous line of research, yet there are numbers of them on problems in acoustics, on acoustics applied to building, on building materials, on the sun spots, on natural history, on the prediction of the changes in the weather, on various problems in meteorology, on capillarity, on light and heat, on the velocity of projectiles, on the correlation of forces, and the conservation of energy.

He was possessed of great foresight. The various forms of electro-motors which have since been attempted are all on the basis of Professor HENRY'S made thirty years ago; nor has all the ingenuity and money expended since that time advanced us one step beyond the conclusion which he reached then. "I never regarded it as practical in the arts because of its great expense of power, except in particular cases where expense of power is of little consequence."

The results of his labors I can only briefly sum up.

As president of the American Association for the Advancement of Science, and of the National Academy of Sciences, he gave the weight of his influence and the benefit of his experience to the successful conduct of these societies.

He was Chairman of the Light-House Board, and during the rebellion, a member of the commission to examine inventions for facilitating military and naval operations.

In these varied capacities he has served the Government with zeal and fidelity, and has made his scientific knowledge of avail in protecting commerce and saving human life; giving to all the arduous duties of these positions his thorough personal supervision. In conjunction with Professor GUYOT, through the agency of the Smithsonian Institution, he first inaugurated the systematic observation and study of the law of storms that has given us our present signal-service observations.

But the greatest triumph of his genius and reward of his patient labor was the discovery of the telegraph. In 1825 Mr. BARLOW, of the Royal Military Academy, published a pamphlet which was accepted as the demonstration that the telegraph was impossible. In 1830 Professor HENRY had a telegraph in successful operation of over a mile and a half in length; and a little later, in Princeton, one of several miles in length. A writer, (Mr. E. N. DICKERSON,) who, as counsel in a patent case, had occasion to examine this matter thoroughly, says: "The thing was perfect as it came from its author, and has never been improved from that day to this as a sounding telegraph." And he further calls attention to the fact that the subsequent invention of an alphabet impressed on paper strips has been abandoned, and, to-day, men read the telegraph phonetically, as Professor HENRY did at the first.

How can we estimate the influence on the world's history, on the progress of nations, on the individual lives of men, of the man who gave to the world, without money and without price, the discovery that made the telegraph possible?

As over the land and under the sea, the voiceless viewless message goes, freighted with its burden of joy or woe, of life or death, of war or peace, it speaks his praise.

This wonderful discovery, beginning a century ago, is the fruit of the combined efforts of great men. OERSTED, ARAGO, AMPÈRE, DAVY, BARLOW, STURGEON, FARADAY—each contributed his share of discovery to the result; but it was reserved for HENRY to apply the discoveries already made, and to add the missing factor that solved the problem and created the electro-magnetic telegraph.

In the later years of his life his arduous and varied duties as head of the Smithsonian Institution hindered in great measure his prosecution of original research. This position he accepted as a sacred trust from its founder, whose simple declaration, that it was to be for the increase and diffusion of knowledge among men, he kept steadily in view. His purity and simplicity of character foiled, as no other armor could have done, the artifice of politicians who sought to wield its influence for political ends. Professor HENRY kept it pure from any such taint, and thus saved it to the nation and the world.

In all his investigations Professor HENRY allowed himself perfect freedom. He followed with simplicity of heart and firmness of mind, whither the revelations of nature led him. He belonged to no scientific clique, was no bigot nor partisan, but calm and unbiased in his conclusions.

But the chief significance of his life to us as Princetonians, as students, and as men, is that he was an humble, sincere, consistent Christian.

The following extract from a letter written April 12, 1878, contains a clear exposition of Professor HENRY'S views. I invite your thoughtful attention to them; they are the well-weighed, mature convictions uttered at the close of a long life of earnest study of nature; and, written but a month before his death, we may regard them as his last testament on this great theme:

"We live in a universe of change; nothing remains the same from one moment till another, and each moment of recorded time has its separate history. We are carried on by the ever-changing events in the line of our destiny, and at the end of the year we are always at a considerable distance from the point of its beginning. How short the space between the two cardinal points of an earthly career, the point of birth and that of death; and yet what a universe of wonders are presented to us in our rapid flight through this space. How small the wisdom obtained by a single life in its passage; and how small the known when compared with the unknown by the accumulation of the millions of lives through the art of printing in hundreds of years.

"How many questions press themselves upon us in these contemplations. Whence come we? Whither are we going? What is our final destiny? The object of our creation? What mysteries of unfathomable depth environ us on every side; but after all our speculations and an attempt to grapple with the problem of the universe, the simplest conception which explains and connects the phenomena is that of the existence of one spiritual Being, infinite in wisdom, in power, and all divine perfections; who exists always and everywhere; who has created us with intellectual faculties sufficient in some degree to comprehend His operations as they are developed in nature by what is called 'science.' - - -

"In accordance with this scientific view, on what evidence does the existence of a Creator rest? First, it is one of the truths best established by experience in my own mind that I have a thinking, willing principle within me, capable of intellectual activity and of moral feeling. Second, it is equally clear to me that you have a similar spiritual principle within yourself, since, when I ask you an intelligent question, you give me an intellectual answer. Third, when I examine operations of nature, I find everywhere through them evidences of intellectual arrangements, of contrivances to reach definite ends precisely as I find in the operations of man; and hence I infer that these two classes of operations are results of similar intelligence. Again, in my own mind I find ideas of right and wrong, of good and evil. These ideas then exist in the universe, and therefore form a basis of our ideas of a moral universe. Furthermore, the conceptions of good which are found among our ideas associated with evil, can be attributed only to a being of infinite perfections like that which we denominate 'God.' On the other hand, we are conscious of having such evil thoughts and tendencies that we can not associate ourselves with a Divine being, who is the director and the governor of all, or even call upon Him for mercy without the intercession of one who may affiliate himself with us."*

Into the kingdom of nature he entered as a little child, and she laid bare her secrets before him; she opened the leaves of her wonderful book, and he read therein, and told us some of her most marvelous secrets, which others had but dimly guessed.

So also into the kingdom of heaven he entered as a little child, and in the same simplicity and sincerity of faith with which he had accepted the truths of nature, he received the word of God.

*This letter of Professor HENRY will be found entire on pages 23-25 of this volume.

There are some who, in these days, tell us that if a man believe in God as his maker, in Christ as his redeemer, in the Holy Spirit as his sanctifier, and in the word of God as the guide of his life, he is no more to be ranked among scientific men, nor fit to be trusted as a student of nature. Where then shall we place this father of American science? Who that vaunts his skeptical conjectures before the world to-day, as the badge of his scientific acumen and liberty of thought, can show so wide, and free, and fair a record of high scientific and beneficent work for his day and generation, as this avowed Christian philosopher?

To those who knew Professor HENRY personally, there was the charm of a singularly gentle and unaffected sincerity of heart and manner, that made him approachable to all. His attachments were warm and lasting. He remembered always with undiminished affection his associates in his professorship at Princeton, and now their children rise up and call him blessed. "None knew him but to love him."

Modest, unassuming, gentle in his deportment, he bore the fruit of Christian faith in his life. Following the example and precepts of his Master, "When he was reviled, he reviled not again; when he was persecuted, he threatened not." He was the model of a Christian gentleman.

And now he has passed from this school, where, by patient labor and with docile heart, he had learned, from the two great books of God, such wondrous lessons of the Divine wisdom and power and love. To-day that noble intellect and simple heart stands, stripped of the clogs of sense, before the unveiled presence of his God, and looks not at the things seen and temporal, but at the things unseen and eternal. With what rapture and amazement there has opened to his view wonders, surpassing immeasurably all that he had guessed on earth, we cannot tell; "for eye hath not seen, nor ear heard, neither have entered into the heart of man the things that God hath prepared for them that love Him."

But who of us, if called to make the choice, would hesitate as to which were the higher honor and which the happier destiny — the place which JOSEPH HENRY, the philosopher, holds, and will ever hold among the great of this world, by virtue of his scientific achievements, or the place which is his at the right hand of God, by virtue of his simple Christian faith? We who love this college, and cherish the memory of the great and good men who have made her name illustrious and sacred, from her foundation to the present hour, feel a thrill of gratification that our illustrious brother was borne to the grave followed by the chief men of the nation, as one whom the people delight to honor. But a higher and tenderer joy fills the heart, when we picture to ourselves his reception at the court of the King of kings, his welcome into the great company of those who are "washed and made white in the blood of the Lamb," and the honor, above all earthly plaudits, when the Master graciously said unto him, "Well done, thou good and faithful servant; enter thou into the joy of thy Lord."

God grant that Princeton College may ever maintain, for American science, the noble succession of such Christian princes in the realms of thought as JOSEPH HENRY.

NOTE.

I have appended a letter, which I received from Professor HENRY, in reply to one soliciting from him some account of his work while connected with the College of New Jersey. While I wish that one better fitted to portray that noble life and enforce its lessons had stood in my place, yet it was a labor of love to pay what tribute I was able to the memory of one who, whenever I met him, spoke in terms of warm affection of my father, who was one of his colleagues.

I now publish it in the hope that it may commend, especially to the students of the college of New Jersey, the noble example of this life, passed in the service of men and the fear of God.

S. B. DOD.

MAY, 1878.

WASHINGTON, D. C., *December 4, 1876.*

MY DEAR SIR: In compliance with your request that I would give an account of my scientific researches during my connection with the College of New Jersey, I furnish the following brief statement of my labors within the period mentioned:

I. Previous to my call from the Albany Academy to a professorship in the College of New Jersey, I had made a series of researches on electro-magnetism, in which I developed the principles of the electro-magnet and the means of accumulating the magnetic power to a great extent, and had also applied this power in the invention of the first electro-magnetic machine; that is, a mechanical contrivance by which electro-magnetism was applied as a motive power.

I soon saw, however, that the application of this power was but an indirect method of employing the energy derived from the combustion of coal, and, therefore, could never compete, on the score of expense, with that agent as a means of propelling machinery, but that it might be used in some cases in which expense of power was not a consideration to be weighed against the value of certain objects to be attained. A great amount of labor has since been devoted to this invention, especially at the expense of the Government of the United States, by the late Dr. CHARLES G. PAGE, but it still remains in nearly the same condition it was left in by myself in 1831.

I also applied, while in Albany, the results of my experiments to the invention of the first electro-magnetic telegraph, in which signals were transmitted by exciting an electro-magnet at a distance, by which means dots might be made on paper, and bells were struck in succession, indicating letters of the alphabet.

In the midst of these investigations I was called to Princeton, through the nomination of Dr. JACOB GREEN, then of Philadelphia, and Dr. JOHN TORREY, of New York.

I arrived in Princeton in November, 1832, and as soon as I became fully settled in the chair which I occupied, I recommenced my investigations, constructed a still more powerful electro-magnet than I had made before—one which would sustain over three thousand pounds,—and with it illustrated to my class the manner in which a large amount of power might, by means of a relay magnet, be called into operation at the distance of many miles.

I also made several modifications in the electro-magnetic machine before mentioned, and just previous to my leaving for England, in 1837, again turned my attention to the telegraph. I think the first actual line of telegraph using the earth as a conductor was made in the beginning of 1836. A wire was extended across the front campus of the college grounds, from the upper story of the library building to the philosophical hall on the opposite side, the ends terminating in two wells. Through this wire, signals were sent, from time to time, from my house to my laboratory. The electro-magnetic telegraph was first invented by me, in Albany, in 1830. Professor MORSE, according to his statements, conceived the idea of an electro-magnetic telegraph in his voyage across the ocean in 1832, but did not until several years afterward—1837—attempt to carry his ideas into practice; and when he did so, he found himself so little acquainted with the subject of electricity that he could not make his simple machine operate through the distance of a few yards. In this dilemma he called in the aid of Dr. LEONARD D. GALE, who was well acquainted with what I had done in Albany and Princeton, having visited me at the latter place. He informed Professor MORSE that he had not the right kind of a battery nor the right kind of magnets, whereupon the professor turned the matter over to him, and, with the knowledge he had obtained from my researches, he was enabled to make the instrument work through a distance of several miles. For this service Professor MORSE gave him a share of his patent, which he afterward purchased from him for $15,000. At the time of making my original experiments on electro-magnetism in Albany, I was urged by a friend to take out a patent, both for its application to machinery and to the telegraph, but this I declined, on the ground that I did not then consider it compatible with the dignity of science to confine the benefits which might be derived from it to the exclusive use of any individual. In this perhaps I was too fastidious. In briefly stating my claims to the invention of the electro-magnetic telegraph, I may say I was the first to bring the electro-magnet into the condition necessary to its use in telegraphy, and also to point out its application to the telegraph, and to illustrate this by constructing a working telegraph, and had I taken out a patent for my labors at that time, Mr. MORSE could have had no ground on which to found his claim for a patent for his invention. To Mr. MORSE however great credit is due for his alphabet, and for his perseverance in bringing the telegraph into practical use.

II. My next investigation, after being settled at Princeton, was in relation to electro-dynamic induction. Mr. FARADAY had discovered that when a current of galvanic electricity was passed through a wire from a battery, a current in an opposite direction was induced in a wire arranged parallel to this conductor. I discovered that an induction of a similar kind took place in the primary conducting wire itself, so that a current which, in its passage through a short wire conductor, would neither produce sparks nor shocks, would, if the wire were sufficiently long, produce both those phenomena. The effect was most strikingly exhibited when the conductor was a flat ribbon, covered with silk, rolled into the form of a helix. With this, brilliant deflagrations and other electrical effects of high intensity were produced by means of a current from a battery of low intensity, such as that of a single element.

III. A series of investigations was afterwards made, which resulted in producing inductive currents of different orders, having different directions, made up of waves alternately in opposite directions. It was also discovered that a plate of metal of any kind, introduced between two conductors, neutralized this induction, and this effect was afterward found to result from a current in the plate itself. It was afterward shown that a current of quantity was capable of producing a current of intensity, and *vice versa*, a current of intensity would produce one of quantity.

IV. Another series of investigations, of a parallel character, was made in regard to ordinary or frictional electricity. In the course of these it was shown that electro-dynamic inductive action of ordinary electricity was of a peculiar character, and that effects could be produced by it at a remarkable distance. For example, if a shock were sent through a wire on the outside of a building, electrical effects could be exhibited in a parallel wire within the building. As another illustration of this, it may be mentioned that when a discharge of a battery of several Leyden jars was sent through the wire before mentioned, stretched across the campus in front of Nassau Hall, an inductive effect was produced in a parallel wire, the ends of which terminated in the plates of metal in the ground in the back campus, at a distance of several hundred feet from the primary current, the building of Nassau Hall intervening. The effect produced consisted in the magnetization of steel needles.

In this series of investigations, the fact was discovered that the induced current, as indicated by the needles, appeared to change its direction with the distance of the two wires, and other conditions of the experiment, the cause of which for a long time baffled inquiry, but was finally satisfactorily explained by the discovery that the discharge of electricity from a Leyden jar is of an oscillatory character, a principal discharge taking place in one direction, and immediately afterward a rebound in the opposite, and so on forward and backward, until the equilibrium is obtained.

V. The next series of investigations related to atmospheric induction. The first of these consisted of experiments with two large kites, the lower end of the string of one being attached to the upper surface of a second kite, the string of each consisting of a fine wire, the terminal end of the whole being coiled around an insulated drum. I was assisted in these experiments by Mr. Brown, of Philadelphia, who furnished the kites. When they were elevated, at a time when the sky was perfectly clear, sparks were drawn of surprising intensity and pungency, the electricity being supplied from the air, and the intensity being attributed to the induction of the long wire on itself.

VI. The next series of experiments pertaining to the same class, was on the induction from thunder clouds. For this purpose the tin covering of the roof of the house in which I resided was used as an inductive plate. A wire was soldered to the edge of the roof near the gutter, was passed into my study and out again through holes in the window-sash, and terminated in connection with a plate of metal in a deep well immediately in front of the house. By breaking the continuity of that part of the wire which was in the study, and introducing into the opening a magnetizing spiral, needles placed in this could be magnetized by a flash of lightning so distant that the thunder could scarcely be heard. The electrical disturbance produced in this case was also found to be of an oscillatory character, a discharge first passing through the wire from the roof to the well, then another in the opposite direction, and so on until equilibrium was restored. This result was arrived at in this case, as well as in that of the Leyden jar, before mentioned, by placing the same, or a similar needle, in succession, in spirals of greater and greater number of turns; for example, in a spiral of a single turn the needle would be magnetized *plus*, or in the direction due to the first and more powerful wave. By increasing the number of coils, the action of the second wave became dominant, so that it would more than neutralize the magnetism produced by the first wave, and leave the needle *minus*. By further increasing the number of turns, the third wave would be so exalted as to neutralize the effects of the preceding two, and so on. In the case of induction by lightning, the same result was obtained by placing a number of magnetizing spirals, of different magnetizing intensities, in the opening of the primary conductor, the result of which was to produce the magnetization of an equal number of needles, plus and minus, indicating alternate currents in opposite directions.

VII. In connection with this class of investigations a series of experiments was made in regard to lightning-rods. It was found that when a quantity of electricity was thrown upon a rod, the lower end of which was connected with a plate of metal sunk in the water of a deep well, that the electricity did not descend silently into water, but that sparks could be drawn from every part of the rod sufficiently intense to explode an electrical pistol and to set fire to delicate inflammable substances. The spark thus given off was found to be of a peculiar character, for while it produced combustion and gave a slight shock, and fired the electrical pistol, it scarcely at all affected a gold leaf electroscope. Indeed, it consisted of two sparks, one from the conductor and the other to it, in such quick succession that the rupture of the air by the first served for the path of the second. The conclusion arrived at was, that during the passage of the electricity down the rod each point in succession received a charge analogous to the statical charge of a prime conductor, and that this charge, in its passage down the rod, was immediately preceded by a negative charge; the two in their passage past the point at which the spark was drawn giving rise to its duplex character. It was also shown by a series of experiments in transmitting a powerful discharge through a portion of air, that the latter, along the path of discharge, was endowed for a moment with an intense repulsive energy. So great is this that in one instance, when an electrical discharge from the clouds passed between two chimneys through the cockloft of a house, the whole roof was lifted from the walls. It is to this repulsive energy, or tendency in air to expand at right angles to the path of a stroke of lightning, that the mechanical effects which accompany the latter are generally to be attributed.

In connection with this series of investigations an experiment was devised for exhibiting the screening effect, within a space inclosed with a metallic envelope, of an exterior discharge of electricity. It consisted in coating the outside of a hollow glass globe with tinfoil, and afterward inserting, through a small hole in the side, a delicate gold leaf electrometer. The latter, being observed through a small opening in the tinfoil, was found to be unaffected by a discharge of electricity passed over the outside coating.

VIII. Another series of investigations was on the phosphorogenic emanation from the sun. It had long been known that when the diamond is exposed to the direct rays of the sun, and then removed to a dark place, it emits a pale blue light, which has received the name of phosphorescence. This effect is not peculiar to the diamond, but is possessed by a number of substances, of which the sulphuret of lime is the most prominent. It is also well known that phosphorescence is produced by exposing the substance to the electric discharge. Another fact was discovered by BECQUEREL, of the French Institute, that the agent exciting phosphorescence traverses with difficulty a plate of glass or mica, while it is transmitted apparently without impediment through plates of black quartz impervious to light.

My experiments consisted, in the first place, in the reproduction of these results, and afterward in the extension of the list of substances which possess the capability of exhibiting phosphorescence, as well as the effects of different interposed media. It was found that, among a large number of transparent solids, some were permeable to the phosphorescing agent, and others impermeable or imperfectly permeable. Among the former were ice, quartz, common salt, alum. Among the latter glass, mica, tourmaline, camphor, etc. Among liquid permeable substances were water, solutions of alum, ammonia; while among the impermeable liquids were most of the acids, sulphate of zinc, sulphate of lead, alcohol, etc.

It was found that the emanation took place from every point of the line of the electric discharge, but with more intensity from the two extremities; and also that the emanation producing phosphorescence, whatever be its nature, when reflected from a mirror obeys the laws of the reflection of light, but no reflection was obtained from a surface of polished glass. It is likewise refracted by a prism of rock salt, in accordance with the laws of the refraction of light. By transmitting the rays from an electrical spark through a series of very thin plates of mica, it was shown that the emanation was capable of polarization, and, consequently, of double refraction.

IX. The next series of investigations was on a method of determining the velocity of projectiles. The plan proposed for this purpose consisted in the application of the instantaneous transmission of the electrical action to determine the time of the passage of the ball between two screens, placed at a short distance from each other in the path of the projectile. For this purpose the observer is provided with a revolving cylinder moving by clock-work at a uniform rate, and of which the convex surface is divided into equal parts indicating a fractional part of a second. The passage of the ball through the screen breaks a galvanic circuit, the time of which is indicated on the revolving cylinder by the terminal spark produced in a wire surrounding a bundle of iron wires. Since the publication of this invention various other plans founded on the same principle have been introduced into practice.

X. Another series of experiments was in regard to the relative heat of different parts of the sun's disk, and especially to that of the spots on the surface. These were made in connection with Professor S. Alexander, and consisted in throwing an image of the sun on a screen in a dark room by drawing out the eye-piece of a telescope.

Through a hole in the screen the end of a sensitive thermo-pile was projected, the wires of which were connected with a galvanometer. By slightly moving the smaller end of the telescope, different parts of the image of the sun could be thrown on the end of the thermo-pile, and by the deviation of the needle of the galvanometer, the variation of the heat was indicated. In this way it was proved that the spots radiated less heat than the adjacent parts, and that all parts of the sun's surface did not give off an equal amount of heat.

XI. Another series of experiments was made with what was called a thermal telescope. This instrument consisted of a long hollow cone of pasteboard, lined with silver leaf and painted outside with lampblack. The angle at the apex of this cone was such as to cause all the parallel rays from a distant object entering the larger end of the cone to be reflected on to the end of a thermo-pile, the poles of which were connected with a delicate galvanometer. When the axis of this conical reflector was directed toward a distant object of greater or less temperature than the surrounding bodies, the difference was immediately indicated by the deviation of the needle of the galvanometer. For example, when the object was a horse in a distant field, the radiant heat from the animal was distinctly perceptible at a distance of at least several hundred yards. When this instrument was turned toward the celestial vault, the radiant heat was observed to increase from the zenith downward; when directed, however, to different clouds, it was found to indicate in some cases a greater, and in others a less, degree of radiation than the surrounding space. When the same instrument was directed to the moon, a slight increase of temperature was observed over that of the adjacent sky, but this increase of heat was attributed to the reflection of the heat of the sun from the surface of the moon, and not to the heat of the moon itself. To show that this hypothesis is not inconsistent with the theory that the moon has cooled down to the temperature of celestial space, a concave mirror was made of ice and a thermo-pile placed in the more distant focus; when a flame of hydrogen, rendered luminous by a spiral platinum wire, was placed in the other focus, the needle of the galvanometer attached to the pile indicated a reflection of heat, care being taken to shade the pile by a screen with a small opening introduced between it and the flame.

XII. Another series of experiments connected with the preceding may be mentioned here. It is well known that the light from a flame of hydrogen is of very feeble intensity; the same is the case with that of the compound blowpipe, while the temperature of the latter is exceedingly high, sufficiently so to melt fine platinum wire. It is also well known that by introducing lime or other solid substance into this flame its radiant light is very much increased. I found that the radiant heat was increased in a similar ratio, or in other words, that in such cases the radiant heat was commensurate with the radiant light, and that the flame of the compound blowpipe, though of exceedingly high temperature, is a comparatively cool substance in regard to radiant heat. To study the relation of the temperature of a flame to the amount of heat given off, four ounces of water were placed in a platinum crucible and supported on a ring stand over a flame of hydrogen; the minutes and seconds of time were then accurately noted which were required for the raising of the water from the temperature of 60° to the boiling point. The same experiment was repeated with an equal quantity of water, with the same flame, into which a piece of mica was inserted by a handle made of a narrow slip of the same substance. With this arrangement the light of the flame was much increased, while the time of bringing the water to the boiling point was also commensurately increased, thus conclusively showing that the increase of light was at the expense of the diminution of the temperature. These experiments were instituted in order to examine the nature of the fact mentioned by Count RUMFORD, that balls of clay introduced into a fire under some conditions increase the heat given off into an apartment. From the results just mentioned it follows that the increase in the radiant heat, which would facilitate the roasting of an article before the fire, would be at the expense of the boiling of a liquid in a vessel suspended directly over the point of combustion.

XIII. Another investigation had its origin in the accidental observation of the following fact: A quantity of mercury had been left undisturbed in a shallow saucer, with one end of a piece of lead wire, about the diameter of a goose-quill, and six inches long, plunged into it, the other end resting on the shelf. In this condition it was found, after a few days, that the mercury had passed through the solid lead, as if it were a siphon, and was lying on the shelf still in a liquid condition. The saucer contained a series of minute crystals of an amalgam of lead and mercury. A similar result was produced when a piece of the same lead wire was coated with varnish, the mercury being transmitted without disturbing the outer surface.

When a length of wire of five feet was supported vertically, with its lower end immersed in a vessel of mercury, the liquid metal was found to ascend, in the course of a few days, to a height of three feet. These results led me to think that the same property might be possessed by other metals in relation to each other. The first attempt to verify this conjecture was made by placing a small globule of gold on a plate of sheet-iron and submitting it to the heat of an assaying furnace; but the experiment was unsuccessful, for although the gold was heated much beyond its melting point, it showed no signs of sinking into the pores of the iron. The idea afterward suggested itself that a different result would have been obtained had the two metals been made to adhere to each other, so that no oxide could form between the two surfaces. To verify this a piece of copper, thickly plated with silver, was heated to near the melting point of the metals, when the silver disappeared, and, after the surface was cleaned with diluted sulphuric acid, it presented a uniform surface of copper. This plate was next immersed for a few minutes in a solution of muriate of zinc, by which the surface of copper was removed and the surface of silver again exposed. The fact had long been observed by workmen in silver-plating, that in soldering the parts of plated metal, if care be not taken not to heat them unduly, the silver will disappear. This effect was supposed to be produced by evaporation, or the burning off, as it was called, of the plating. It is not improbable that a slow diffusion of one metal into the other takes place in the case of an alloy. Silver coins slightly alloyed with copper, after having lain long in the earth, are found covered with a salt of copper. This may be explained by supposing that the alloy of copper at the surface of the coin enters into combination with the carbonic acid of the soil, and being thus removed, its place is supplied by a diffusion from within, and so on; it is not improbable that a large portion of the alloy may be removed in progress of time, and the purity of the coin be considerably increased. It is known to the jeweler that articles of copper plated with gold lose their brilliancy after awhile, and that this can be restored by boiling them in ammonia. This effect is probably produced by the ammonia acting on the copper and dissolving off its surface so as to expose the gold, which by diffusion had penetrated into the body of the metal.

The slow diffusion of one metal into another at ordinary temperatures would naturally require a long time to produce a perceptible effect, since it is probably only produced by the minute vibrations of the particles due to variations of temperature.

The same principle is applied to the explanation of the phenomenon called segregation—such as the formation of nodules of flint in masses of carbonate of lime, or in other words, to the explanation of the manner in which the molecular action, which is insensible at perceptible distances, may produce results which would appear, at first sight, to be the effect of attraction acting at a distance.

XIV. Another series of experiments had reference to the constitution of matter in regard to its state of liquidity and solidity, and they had their origin in the examination of the condition of the metal of the large gun constructed under the direction of Captain STOCKTON, by the explosion of which several prominent members of the United States Government were killed at Washington. It was observed in testing the bars of iron made from this gun that they varied much in tensile strength in different parts, and that in breaking these bars the solution of the continuity took place first in the interior. This phenomenon was attributed to the more ready mobility of the outer molecules of the bars, the inner ones being surrounded by matter incapable of slipping, and hence the rupture. A similar effect is produced in a piece of thick copper wire, each end when broken exhibiting at the point of rupture a cup-shaped surface, showing that the exterior of the metal sustained its connection longer than the interior.

From these observations the conclusion was drawn, that rigidity differs from liquidity more in a polarity which prevents slipping of the molecules, than in a difference of the attractive force with which the molecules are held together; or that it is more in accordance with the phenomena of cohesion, to suppose that in the case of a liquid, instead of the attraction of the molecules being neutralized by heat, the effect of this agent is merely to neutralize the polarity of the molecules, so as to give them perfect freedom of motion around any imaginable axis. In illustration of this subject the comparative tenacity of pure water in which soap had been dissolved, was measured by the usual method of ascertaining the weight required to detach from the surface of each the same plate of wood, suspended from the beam of a balance, under the same condition of temperature and pressure. It was found by this experiment that the tenacity of pure water was greater than that of soap and water. This novel result is in accordance with the supposition that the mingling of the soap and the water interferes with the perfect mobility of the molecules, while at the same time it diminishes the attraction.

XV. A series of experiments was also made on the tenacity of soap-water in films. For this purpose sheets of soap-water films were stretched upon rings, and the attempt made to obtain the tenacity of these by placing on them pellets of cotton until they were ruptured. The thickness of these films was roughly estimated by NEWTON'S scale of the colors of thin plates, and from the results the conclusion was arrived at that the attractive force of the molecules of water, for those of water, is approximately equal to those of ice for those of ice, and that the difference in this case, of the solidity and liquidity, is due to the want of mobility in the latter, which prevented the slipping of the molecules on each other. It is this extreme mobility of the molecules of water that prevents the formation of permanent bubbles of it, and not a want of attraction.

The roundness of drops of water is not due to the attraction of the whole mass, but merely to the action of the surface, which in all cases of curvature is endowed with an intense contractile power.

This class of investigation also included the study of soap bubbles, and the establishment of the fact of the contractile power of these films. The curvature of the surface of a bubble tends to urge each particle toward the center with a force inversely as the diameter. Two bubbles being connected, the smaller will collapse by expelling its contents into the larger. By employing frames of wire, soap bubbles were also made to assume various forms, by which capillarity and other phenomena were illustrated. This subject was afterward taken up by PLATEAU, of Ghent. Another part of the same investigation was the study of the spreading of oil on water, the phenomenon being referred to the fact that the attraction of water for water is greater than that of oil for oil, while the attraction of the molecules of oil for each other is less than the attraction of the same molecules for water; hence the oil spreads over the water. This is shown from the fact that when a rupture is made in a liquid compound, consisting of a stratum of oil resting on water, the rupture takes place in the oil, and not between the oil and water. The very small distance at which the attraction takes place is exhibited by placing a single drop of oil on a surface of water of a considerable extent, when it will diffuse itself over the whole surface. If however a second drop be placed upon the same surface, it will retain its globular form.

XVI. Another contribution to science had reference to the origin of mechanical power and the nature of vital force. Mechanical power is defined to be that which is capable of overcoming resistance; or in the language of the engineer, that which is employed to do work.

If we examine attentively the condition of the crust of the earth, we find it, as a general rule, in a state of permanent equilibrium. All the substances which constitute the material of the crust, such as acids and bases, with the exception of the indefinitely thin pellicle of vegetable and animal matter which exists at its surface, have gone into a state of permanent combination, the whole being in the condition of the burnt slag of a furnace, entirely inert, and capable in itself of no change. All the changes which we observe on the surface of the globe may be referred to action from without, from celestial space.

The following is a list which will be found to include all the prime movers used at the present day, either directly or indirectly, in producing molecular changes in matter:

CLASS I.	Water power. Tide power. Wind power.	Immediately referable to celestial disturbance.
CLASS II.	Steam and other powers developed by combustion. Animal power.	Immediately referable to what is called vital action.

The forces of gravity, cohesion, electricity, and chemical attraction tend to produce a state of permanent equilibrium on our planet; hence these principles in themselves are not primary, but secondary agents in producing mechanical effects. As an example, we may take the case of water-power, which is approximately due to the return of the water to a state of stable equilibrium on the surface of the ocean; but the primary cause of the motion is the force which produced the elevation of the liquid in the form of vapor—namely, the radiant heat of the sun. Also in the phenomena of combustion, the immediate source of the power evolved in the form of heat is the passage from an unstable state into one of stable combination of the carbon and hydrogen of the fuel with oxygen of the atmosphere. But this power may ultimately be resolved into the force which caused the separation of these elements from their previous combination in the state of carbonic acid—namely, the radiant light of the sun. But the mechanical power exerted by animals is due to the passage of organized matter in the stomach from an unstable to a stable equilibrium, or as it were from the combustion of the food. It therefore follows that animal power is referable to the same source as that from the combustion of fuel—namely, developed power of the sun's beams. But according to this view, what is vitality? It is that mysterious principle—not mechanical power—which determines the form and arranges the atoms of organized matter, employing for this purpose the power which is derived from the food.

These propositions were illustrated by different examples. Suppose a vegetable organism impregnated with a germ (a potato, for instance) is planted below the surface of the ground in a damp soil, under a temperature sufficient for vegetation. If we examine it from time to time, we find it sending down rootlets into the earth, and stems and leaves upward into the air. After the leaves have been fully expanded we shall find the tuber entirely exhausted, nothing but a skin remaining. The same effect will take place if the potato be placed in a warm cellar; it will continue to grow until all the starch and gluten are exhausted, when it will cease to increase. If however we now place it in the light, it will commence to grow again, and increase in size and weight. If we weigh the potato previous to the experiment, and the plant after it has ceased to grow in the dark, we shall find that the weight of the latter is a little more than half that of the original tuber. The question then is, what has become of the material which filled the sac of the potato? The answer is, one part has run down into carbonic acid and water, and in this running down has evolved the power to build up the other part into the new plant. After the leaves have been formed and the plant exposed to the light of the sun, the developed power of its rays decomposes the carbonic acid of the atmosphere, and thus furnishes the pabulum and the power necessary to the further development of the organization. The same is the case with wheat, and all other grains that are germinated in the earth. Besides the germ of the future plant, there is stored away, around the germ, the starch and gluten to furnish the power necessary to its development, and also the food to build it up until it reaches the surface of the earth and can draw the source of its future growth from the power of the sunbeam. In the case of fungi and other plants that grow in the dark, they derive the power and the pabulum from surrounding vegetable matter in process of decay, or in that of evolving power. A similar arrangement found is in regard to animal organization. It is well known that the egg continually diminishes in weight during the process of incubation, and the chick, when fully formed, weighs scarcely more than one-half the original weight of the egg. What is the interpretation of this phenomenon? Simply that one part of the contents of the shell has run down into carbonic acid and water, and thus evolved the power necessary to do the work of building up the future animal. In like manner when a tadpole is converted into a frog, the animal, for a while, loses weight; a portion of the organism of its tail has been expended developing the power necessary to the transformation, while another portion has served for the material of the legs.

What then is the office of vitality? We say that it is analogous to that of the engineer who directs the power of the steam-engine in the execution of its work. Without this, in the case of the egg, the materials, left to the undirected force of affinity, would end in simply producing chemical compounds — sulphureted hydrogen, carbonic acid, etc. There is no special analogy between the process of crystallization and that of vital action. In the one case definite mathematical forms are the necessary results, while in the other the results are precisely like those which are produced under the direction of will and intelligence, evincing a design and a purpose, making provision at one stage of the process for results to be attained at a later, and producing organs intended evidently for locomotion and perception. Not only is the result the same as that which is produced by human design, but in all cases the power with which this principle operates is the same as that with which the intelligent engineer produces his result.

This doctrine was first given in a communication to the American Philosophical Society, in December, 1844, and more fully developed in a paper published in the Patent Office Report in 1857.

The publication, in full, of three of the series of investigations herein described, was made in the "Transactions of the American Philosophical Society." Others were published in "Silliman's Journal," and both these are noticed in the "Royal Society's Catalogue of Scientific Papers;" but the remainder of them were published in the "Proceedings of the American Philosophical Society," and are not mentioned in the work just referred to.

In 1846, while still at Princeton, I was requested by members of the Board of Regents of the Smithsonian Institution, which was then just founded, to study the will of Smithson, and to give a plan of organization by which the object of the bequest might be realized. My conclusion was that the intention of the donor was to advance science by original research and publication, that the establishment was for the benefit of mankind generally, and that all unnecessary expenditures on local objects would be violations of the trust. The plan I proposed for the organization of the Institution was to assist men of science in making original researches, to publish these in a series of volumes, and to give a copy of these to every first-class library on the face of the earth.

I was afterward called to take charge of the Institution, and to carry out this plan, which has been the governing policy of the establishment from the beginning to the present time.

One of the first enterprises of the Smithsonian Institution was the establishment of a system of simultaneous meteorological observations over the whole United States, especially for the study of the phenomena of American storms. For this purpose the assistance of Professor ARNOLD GUYOT was obtained, who drew up a series of instructions for the observers, which was printed and distributed in all parts of the country. He also recommended the form of instruments best suited to be used by the observers, and finally calculated, with immense labor, a volume of meteorological and physical tables for reducing and discussing observations. These tables were published by the Institution, and are now in use in almost every part of the world in which the English language is spoken. The prosecution of the system finally led to the application of the principles established to the predictions of the weather by means of the telegraph.

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