Address on the scientific life and labors of William C. Redfield, A.M., first president of the American Association for the Advancement of Science : delivered before the Association at their Annual Meeting in Montreal, August 14, 1857 / by Denison Olmsted.

Olmsted (D.)

ADDRESS

ON THE

SCIENTIFIC LIFE AND LABORS

OF

WILLIAM C. REDFIELD, A. M.,

FIRST PRESIDENT OF THE

American Association for the Advancement of Science.

DELIVERED BEFORE THE ASSOCIATION

AT THEIR ANNUAL MEETING IN MONTREAL,

AUGUST 14, 1857.

Box 10

BY DENISON OLMSTED, LL.D.,
Professor of Natural Philosophy and Astronomy in Yale College.

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NEW HAVEN:
PRINTED BY E. HAYES.
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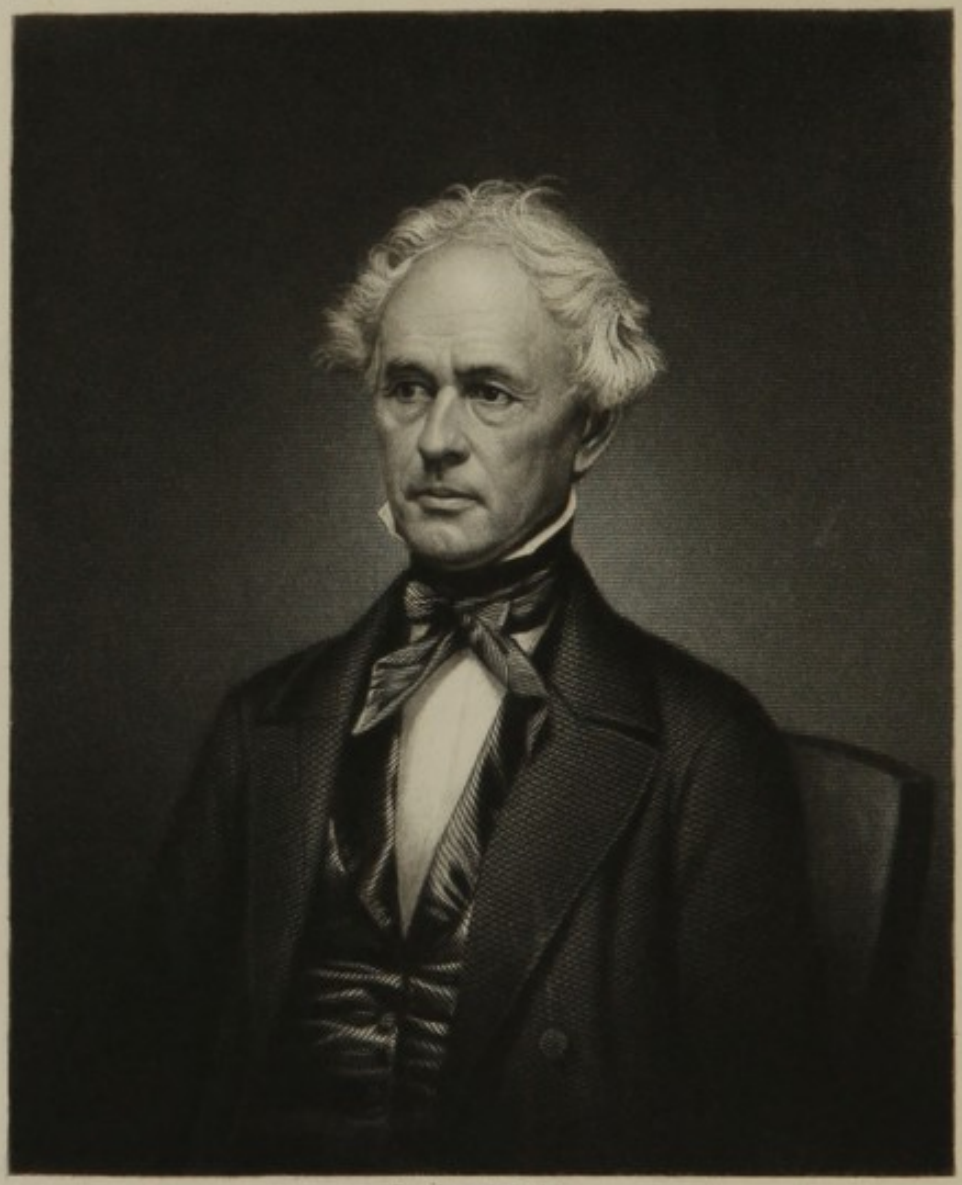

Engd by A.H.Ritchie

Yours truly

Wm C. Redfield

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ADDRESS.

Gentlemen of the Association:

SINCE last we met, the Destroyer has been very busy in our ranks. Besides other beloved and respected associates, our earliest and our latest Presidents have suddenly vanished from our midst;—*Redfield*, who was the first to suggest the idea of the American Association on its present comprehensive plan, and the first to preside over its deliberations, and *Bailey* who, we fondly hoped, would occupy the same distinguished position on the present occasion. From the vision of both, as we humbly trust, the veil which permits us here to see only through a glass darkly, is removed, and the grand laws of Nature, and the infinitessimal no less than the infinite in God's works, are revealed to them in the clear light of heaven.

With Mr. Redfield my acquaintance has been long and intimate. I was conversant with his earliest researches on the subject which is so closely associated with his name, and I have been constantly a witness of his untiring self-sacrificing labors in the cause of science, through all the subsequent years of his life. I respected him as a man, I admired him as a philosopher, I loved him as a friend. We miss him here, always the earliest to come and the latest to depart. We miss his gentle tones, his kindly greetings. We miss still more the radiance which his clear mind cast upon our pathway up the hill of science. I am thankful for the opportunity of presenting before this learned assembly a synopsis of his scientific labors. Some brief notice, also, of his personal history may be acceptable, not only

to satisfy the wishes of his friends, but for the benefit of his example, which, I trust, will especially commend itself to the self-taught votary of science, and to all who are engaged in the pursuit of knowledge under difficulties, both as an incentive and a model. A life passed in the ordinary walks of business, or in the quiet of philosophical research, affords little of that romantic incident which lends a charm to biography; still we think the life of Mr. Redfield affords an interesting and instructive theme for contemplation in a three-fold point of view,—as affording a marked example of the successful pursuit of knowledge under difficulties,—as happily illustrating the union, in the same individual, of the man of science with the man of business,—and as exhibiting a philosopher, whose researches have extended the boundaries of knowledge, and greatly augmented the sum of human happiness.

William C. Redfield was born at Middletown, Connecticut, on the 25th of March, 1789. He was of pure English descent both by the father's and mother's side. His father from a natural love of adventure, chose in early youth a sea-faring life, and afterwards followed the seas as a profession to the time of his death, which happened when this, his eldest son, was only thirteen years old. His early training, therefore, devolved chiefly on his mother, who was a woman of superior mental endowments, and of exalted Christian character.

The slender pecuniary resources of the family would not allow young Redfield any opportunities of school education beyond those of the common schools of Connecticut, which, at that time, taught little more than the simplest rudiments—reading, spelling, writing, and a little arithmetic; and all access to the richer treasures of knowledge seemed to be forever denied him, when, at the early age of fourteen, he was removed to Upper Middletown, now called Cromwell, and apprenticed to a mechanic, whose tasks engrossed every moment of his time except a part of his evenings. These brief opportunities, however, he most diligently spent in the acquisition of knowledge, eagerly devouring every scientific work within his reach. He was denied even a lamp for reading by night, much of the time during his apprenticeship,

and could command no better light than that of a common wood fire in the chimney corner. Under all these disadvantages, it is evident that before he was twenty-one years of age he had acquired no ordinary amount and variety of useful knowledge. During the latter part of his apprenticeship he united with other young men of the village in forming a debating society under the name of the "Friendly Association," with which was connected a small but growing library. To this humble literary club, Mr. Redfield always ascribed no small agency in inspiring him with a love of knowledge, and a high appreciation of its advantages; and during his future years, he nursed and liberally aided by his contributions this benefactor of his youth.

Fortunately for young Redfield, a distinguished and learned physician, Dr. William Tully, fixed his residence in the same village, and generously opened to him his extensive and well-selected library; and what must have been equally inspiring to youthful genius, Dr. Tully furnished him with a model of an enthusiastic devotee to knowledge, and of a mind richly stored with intellectual wealth. The modest youth who first presented himself as a suppliant for the loan of a book from the Doctor's library, was soon recognized as a congenial spirit, and was admitted to an intimate friendship, which lasted to the day of his death. Dr. Tully has favored us with the particulars of his first acquaintance with our friend. On his application for a book to occupy such moments as he could redeem from his daily tasks, the Doctor, being then ignorant of his acquirements or his taste, opened different cases of his library, submitting the contents of each to his selection. Among a great variety of authors, that which determined his choice was Sir Humphry Davy's Elements of Chemistry. As this was one of the earliest systematic works that contained the doctrine of Chemical Equivalents, a subject then considered as peculiarly difficult, and one understood by few readers of the work, the Doctor had little expectation that his young inquirer after knowledge, would either understand or relish it. In a short time he returned the book, and surprised the Doctor by evincing a thorough acquaintance with its contents, and expressing a high satisfaction, in particular, with the doctrine of chemical equivalents, which, he said, he had then met with for the first time.

Some time before young Redfield reached the end of his apprenticeship, his widowed mother had married and removed to the state of Ohio. He was no sooner master of his time than he set out on foot to pay her a visit in her new home, distant more than seven hundred miles. It was a formidable undertaking, in that early period before the age of steamboats and railways, and when a large part of the way was covered with dense forests, with hardly an open path even for the pedestrian. Stage coaches, indeed, ran on the nearer portions of the route, but these were too expensive for the slender finances of our young adventurer. Accompanied, therefore, by two other young men, he shouldered his knapsack and commenced the arduous journey. Every evening he noted down the incidents and observations of the day. This journal is now in my possession, and I have perused it with deep interest for the graphic sketches it contains of the countries he passed through, then mostly new settlements, and for the indications it affords of those powers of observation, which afterwards led to the development of the laws of storms. The style of composition is far superior to what might reasonably have been expected from one who had enjoyed so few literary advantages, evincing two qualities for which Mr. Redfield was always distinguished—good sense and good taste. The sketches of Western New York, and of Northern Ohio, taken while the sites of Rochester and Cleveland were dark and gloomy forests, and Buffalo was a mere hamlet, possess no ordinary degree of historical interest. Instead of a "Lake Shore" road, traversed by the iron horse, as at present, our young pedestrians could find no better paths in which to travel over the southern side of Lake Erie, than to course along the beach. Yet in twenty-seven days they made good their journey, having rested four days on the way, making an average of about thirty-two miles per day. After passing the winter with his friends in Ohio, he resumed his way homeward on foot and alone, returning by a more southern route, through parts of the states of Virginia, Maryland, and Pennsylvania. We shall soon see to what valuable account he afterwards turned the observations made on these early pedestrian tours, in tracing the course as well as originating the project, of a great railway connecting the Hudson and the Mississippi rivers.

Returning to his former home in 1811, Mr. Redfield commenced the regular business of life. No circumstances could seem more unpropitious to his eminence as a philosopher, than those in which he was placed for nearly twenty years after his first settlement in business. A small mechanic in a country village, eking out a scanty income by uniting with the products of his trade the sale of a small assortment of merchandize, Mr. Redfield met with obstacles which in ordinary minds would have quenched the desire of intellectual progress. Yet every year added largely to his scientific acquisitions, and developed more fully his intellectual and moral energies. Meanwhile his active mind left its impress on the quiet community where he lived, in devising and carrying out various plans for advancing their social comfort and respectability, in the improvement and embellishment of their streets, school houses and churches, and in promoting the interests of the literary club, from which he himself, in early youth, had derived such signal advantages. From deep domestic trials which afflicted him about the year 1820, he had recourse for solace both to the word and the works of God. It was soon after one of the severest of these trials, that his attention was first directed to the subject of Atlantic Gales.

On the 3d of September, 1821, there occurred, in the eastern part of Connecticut, one of the most violent storms ever known there, and long remembered as the "great September Gale." Shortly after this, Mr. Redfield being on a journey to the western part of Massachusetts, happened to travel over a region covered by marks of the ravages of the recent storm. He was accompanied by his eldest son, then a young lad, who well remembers these early observations of his father, and the inferences he drew from them. At Middletown, the place of Mr. Redfield's residence, the gale commenced from the southeast, prostrating the trees towards the northwest; but on reaching the northwestern part of Connecticut, and the neighboring parts of Massachusetts, he was surprised to find that there the trees lay with their heads in the opposite direction, or towards the southeast. He was still more surprised to find, that at the very time when the wind was blowing with such violence from the *southeast* at Middletown, a *northwest* wind was blowing with equal violence at a point less

than seventy miles distant from that place. On tracing further the course and direction of prostrated objects, and comparing the times when the storm reached different places, the idea flashed upon his mind that the storm was a *progressive whirlwind.* A conviction thus forced upon his mind after a full survey of the facts was not likely to lose its grasp. Amid all his cares, it clung to him, and was cherished with the enthusiasm usual to the student of nature, who is conscious of having become the honored medium of a new revelation of her mysteries. Nothing, however, could have been further from his mind, than the thought that the full development of that idea, would one day place him among the distinguished philosophers of his time. So little, indeed, did he dream of fame, that for eight or nine years after the first conception of his theory, he gave little attention to the study of the phenomena of storms, but was deeply engrossed in other enterprises which, although foreign to this subject, were alike evincive of his original and inventive turn of mind. Of these we may take a passing notice.

Before the scientific world, Mr. Redfield has appeared so exclusively in the character of a philosopher, especially of a meteorologist, that they have been hardly aware of the important services he has rendered the public in the character of *naval engineer*, particularly in the department of steamboat navigation. His attention was turned professionally towards this subject as early as the year 1820, when he became much interested in an experiment with a small boat propelled by an engine of new and peculiar construction, the invention of Franklin Kelsey, Esq., a townsman of his. Although the enterprize was not successful to the company, yet to himself it was not destitute of valuable results, as it was the occasion of his acquiring a more intimate knowledge of the properties of steam, of steam navigation, and of ship building. On the ruins of that enterprize was erected another, which after some vicissitudes acquired a permanent success, and opened to him a sphere of professional labor which constituted ever afterwards the leading object of his life, as a man of business. Several disastrous steamboat explosions had spread alarm through the community and created a general terror of steamboats. Redfield was the first to devise and carry into exe-

cution the plan of a line of *safety barges* to ply on the Hudson between New York and Albany. The scheme was, to construct a passenger boat to be towed by a steamboat at such a distance from it as to avoid all apprehension of danger to the passengers. Large and commodious barges were built, fitted up with greater taste and luxury than had at that time been exhibited by steamboats. With these were connected two large and substantial steamers; and in the excited state of the public mind, these safety barges became great favorites with travellers, especially with parties of pleasure. But our countrymen never hold their fears long: a short interval of exemption from steamboat accidents ended the excitement, while the greater speed attained by the ordinary boats, and the lower fare, gradually drew off passengers from the safety barges, until they could be no longer run with profit to the company, and were abandoned. But the idea was not without profit, for it suggested to him the system of *tow boats* for conveying freight, which was established in the spring of 1826, and still continues under its original organization. The fleets of barges and canal boats, sometimes numbering forty or fifty, which make so conspicuous a figure on the Hudson river, were thus set in movement by Mr. Redfield, and for thirty years the superintendence of the line first established, constituted the appropriate business of our friend. In its management he employed unwearied industry, superior mechanical genius for contriving expedients, and a knowledge of both the science and art of steam navigation, possessed by few men of business. Seldom have we seen the inductive philosopher so happily united with the practical engineer, each character borrowing aid from the other. I know not that any other man connected with the management of a steam-navigation concern, as his profession, ever carried into his business more of the spirit of true science, and it is chiefly on this account that I have thought it fitting to attend our associate into the familiar walks of business, for the purpose of seeing how compatible, and how productive of useful results is the happy union, in the same person, of the philosopher and the man of business. No one else could have so thoroughly collected the statistics of the profession in this country, embracing all the facts relating to the explosion of

steamboat boilers, as they successively occurred—the number of lives lost—the number of deaths by steam compared with those by lightning—and the number compared with those lost by other modes of travel. Moreover, while Mr. Redfield was diligently pursuing his daily business and conducting with success the affairs of the "Steam Navigation Company," he was also collecting facts for the improvement of the art itself, or for securing the safety of passengers. He devised simpler, cheaper, and safer forms of apparatus than those in general use. He investigated the influence of legal enactments for regulating steam navigation, and pointed out to legislatures and governments the inefficacy or inexpediency of such enactments, and suggested the true measures to be taken to promote the convenience and secure the safety of the public. He addressed a series of letters through the public prints to one of our prominent naval commanders, setting forth the adaptedness of steam as an agent of national defense. He responded to the call of the Secretary of the United States Treasury to point out the causes of steamboat explosions, and to suggest the means of safety. Happy would it be, if in all the great operations of the mechanical arts, the true spirit of the philosopher were so fully conjoined with the practical knowledge and skill of the engineer. How rapid would be the improvement of the arts! How science and art would walk hand in hand, and mutually aid and illustrate each other!

We turn now to another subject which engaged the attention of Mr. Redfield, and brought into exercise his remarkable sagacity and forecast. He was the first to place before the American people the plan of a system of railroads connecting the waters of the Hudson with those of the Mississippi. His pamphlet containing this project, issued in 1829, is a proud monument of his enlarged views, of his accurate knowledge of the topography of the vast country lying between these great rivers, of his extraordinary forecast, anticipating as he did the rapid settlement of the western states, the magic development of their agricultural and mineral wealth, and the consequent rapid growth of our great commercial metropolis. The route proposed is substantially that of the New York and Erie railroad as far as this goes; but his views extended still further, and he marked out,

with prophetic accuracy, the course of the railroads which would connect with the Atlantic states, the then infant states of Michigan, Indiana, and Illinois. These, he foresaw, would advance with incredible rapidity the settlement of those regions of unbounded fertility, and would divert no small portion of the trade from the Mississippi to the great metropolis of the east.

It must be borne in mind that railroads for general transportation were unknown in this country until 1826, when the project of constructing the Albany and Schenectady railroad was first entertained. As yet the advantages of railroads had not with us been practically demonstrated, and especially their advantages over canals were not generally understood or appreciated. At the moment when the Erie canal, having just been completed, was at the summit of its popularity, Mr. Redfield set forth in his pamphlet, under nineteen distinct heads, the great superiority of railroads to canals, advantages which, although then contemplated only in theory, have been fully established by subsequent experience. He had even anticipated that after the construction of the proposed great trunk railway connecting the Hudson and the Mississippi, many lateral railways and canals would be built, which would bind in one vast net-work the whole great west to the Atlantic states. "This great plateau (says he) will indeed one day be intersected by thousands of miles of railroad communications; and so rapid will be the increase of its population and resources, that many persons now living will probably see most or all of this accomplished." How well has this remarkable prediction, uttered in 1829, when there was not a foot of railroad in all the country under review, been fulfilled, and how truly has it happened that many of the elder members of this association still live to witness its accomplishment!

The motives which impelled Mr. Redfield to spread this subject before the American people at that early day, when railroads were scarcely known in this country, were purely patriotic. He had no private interests to subserve in the proposed enterprize, and the whole expense of preparing and publishing two editions of the pamphlet embodying these enlarged and prophetic views, was defrayed from his own limited resources.

In 1832, Mr. Redfield, in company with Mr. Morgan, civil engineer, reconnoitered the series of interior valleys through which the Harlem railroad now runs, with a view to the establishment of the New York and Albany railroad. He was instrumental in obtaining the charter of that road, and published a pamphlet entitled "Facts and Suggestions relating to the New York and Albany Railroad." About the same period, in connection with James Brewster, Esq. of New Haven, he explored the route of a railroad leading from New Haven to Hartford, which afterwards resulted in the construction of the Hartford and New Haven railroad. As early as 1829, he addressed a memorial to the Common Council of the City of New York, asking permission to lay an experimental railroad in Canal street. The project of a railroad through one of the public streets of New York was at that time considered as chimerical, but time has developed the wisdom of the plan, and illustrated the sagacity and forecast that first devised it.

When the project of the Hudson River Railroad was started, he entered into it with his characteristic enthusiasm, and was a member of the board of directors, which brought that road to its final completion. In the progress of the work he was deeply interested, frequently visiting all parts of the line, and at different periods examining on foot the entire road between New York and Albany. His associates of the board acknowledged themselves indebted to him for many valuable suggestions relating to its construction.*

But we turn from these noble enterprises in which the philosopher and the engineer were happily united in the same individual, to the consideration of the great subject which, from this time, formed the leading object of his life, namely, to perfect his *theory of storms.* Nor do we turn away from great practical subjects to such as are merely speculative. The lives and property which

* From the outset Mr. Redfield maintained that the low rate of fares at first adopted would prove inadequate to sustain the road, and published in the papers of that day a series of articles to show that the road could not be supported at a less rate than two cents per mile. These views met with much opposition at the time, not only from residents on the line of the road, but from members of the board of directors. But the result has proved the soundness of his judgment on that point.

Redfield's disinterested labors in behalf of steam navigation contributed to save, would, we believe, be of small amount compared with the sailors and ships which the rules founded on his theory of storms, when fully applied to practice, will save from shipwreck.

We have already seen that the attention of Mr. Redfield was first drawn to the subject of storms in the year 1821, by examining the position of trees prostrated by the great September gale, which passed over Connecticut and the western part of Massachusetts that year. Although he had never lost sight of the theory of storms, yet the multifarious business concerns which engrossed the greater part of his time for a number of years afterwards, prevented his bringing it distinctly before the public until the year 1831. I chanced at that period to meet him for the first time on board a steamboat on the way from New York to New Haven. A stranger accosted me, and modestly asked leave to make a few inquiries respecting some observations I had recently published in the American Journal of Science on the subject of Hailstorms. I was soon made sensible that the humble inquirer was himself a proficient in meteorology. In the course of the conversation, he incidentally brought out his theory of the laws of our Atlantic gales, at the same time stating the leading facts on which his conclusions were founded. This doctrine was quite new to me, but it impressed me so favorably, that I urged him to communicate it to the world through the medium of the American Journal of Science. He manifested much diffidence at appearing as an author before the scientific world, professing only to be a practical man little versed in scientific discussions, and unaccustomed to write for the press. At length, however, he said he would commit his thoughts to paper, and send them to me, on condition that I would revise the manuscript and superintend the press. Accordingly, I soon received the first of a long series of articles on the laws of storms, and hastened to procure its insertion in the Journal of Science. Some few of the statements made in this earliest development of his theory, he afterwards found reason for modifying; but the great features of that theory appear there in bold relief. Three years afterwards he published, in the 25th

volume of the same journal, an elaborate article on the Hurricanes of the West Indies, in the course of which he gives a full synopsis of the leading points of his doctrine, as matured by a more extended analysis of the phenomena of storms than he had made when he published his first essay.

Possibly some of those whom I have the pleasure to address, may not have fully acquainted themselves with Redfield's theory of storms, and would desire to be informed of its leading principles. I understand this theory to be substantially as follows:

That all violent gales or hurricanes are great *whirlwinds*, in which the wind blows in circuits around an axis either vertical or inclined; that the winds do not move in horizontal circles, as the usual form of his diagrams would seem to indicate, but rather in spirals towards the axis, a descending spiral movement externally and ascending internally.

That the *direction of revolution* is always uniform, being from right to left, or against the sun, on the north side of the equator, and from left to right, or with the sun, on the south side.

That the *velocity of rotation* increases from the margin towards the center of the storm.

That the whole body of air subjected to this spiral rotation is, at the same time, *moving forward* in a path, at a variable rate, but always with a velocity much less than its velocity of rotation, being at the minimum, hitherto observed, as low as four miles, and at the maximum forty-three miles, but more commonly about thirty miles per hour, while the motion of rotation may be not less than from one hundred to three hundred miles per hour.

That in storms of a particular region, as the gales of the Atlantic, or the typhoons of the China seas, *great uniformity exists in regard to the path pursued,* those of the Atlantic, for example, usually issuing from the equatorial regions eastward of the West India islands, pursuing, at first, a course towards the northwest as far as the latitude of 30°, and then gradually wheeling to the northeast and following a path nearly parallel to the American coast, to the east of Newfoundland, until they are lost in mid-ocean, the entire path when delineated resembling a parabolic curve whose apex is near the latitude of 30°.

That their *dimensions* are sometimes very great, being not less than 1000 miles in diameter, while their path over the ocean can sometimes be traced for 3000 miles.

That the *barometer*, at any given place, falls with increasing rapidity as the center of the whirlwind approaches, but rises at a corresponding rate after the center has passed by; and finally,

That the phenomena are more uniform in large than in small storms, and more uniform on the ocean than on the land.

These laws Mr. Redfield claims as so many *facts* independently of all hypothesis; as facts deduced from the most rigorous induction, which will ever hold true, whatever views may be entertained respecting the origin or causes of storms.

The *method* adopted by the author of this theory, in all his inquiries,—the method which first led him to the discovery of the whirlwind character of storms, and afterwards fully confirmed the doctrine,—was first to collect and then to collate as many records as possible of vessels that had been caught in the storm, in various parts of the ocean. The most laborious and profound investigation of this nature of which he has left us an example, is in the case of the Cuba hurricane of October, 1844. First, he examined all accessible marine reports of vessels that had arrived in port after encountering the storm; secondly, he inspected the log-books of all such vessels, as far as was practicable, and carefully transcribed their records; and, thirdly, by an extended correspondence, he obtained a great number of written statements from shipmasters, who of all men would be the most accurate and vigilant observers. The different independent accounts obtained from these various sources amounted to no less than one hundred and sixty-four, all of which were reduced to the form of tables, containing the latitude and longitude of each vessel or place at the time of observation; the exact date and duration of the gale; the successive directions of the storm-wind; the state of the barometer; and, finally, every additional particular that was deemed of the least importance in determining the peculiar characteristics of the storm. With these data before him, he spread out a marine chart, and having noted on it the position of each vessel and place with the direction and force of the wind, the plot itself proclaimed to the eye the whirl-

wind character of the storm; and the comparison of dates, and corresponding courses of the winds, and respective states of the barometer, showed the dimensions of the storm, its rotary and progressive velocities, its duration at any given place, and its various degrees of violence at different distances from the center. In the character of the researches before us, conducted as they were, not in the shades of philosophic retirement and learned leisure, but in hours redeemed from the pressing avocations of an onerous and responsible business, or borrowed from the season allotted to sleep, we trace qualities of mind that belong only to the true philosopher.

The benevolent and practical mind of Redfield had no sooner established the laws of storms, than it commenced the inquiry, what rules may be derived from it, to promote the safety of the immense amount of human life and of property that are afloat on the ocean, and exposed continually to the dangers of shipwreck; in this imitating our Franklin, who as soon as he had discovered the identity of lightning with the electricity of our machines, hastened to the inquiry, How may we so apply our knowledge of the laws of electricity as to disarm the thunderbolt of its terrors? We might pursue the comparison and say, that as every building saved from the ravages of lightning by the conducting rod, is a token both of the sagacity and the benevolence of Franklin, so every vessel saved from the horrors of shipwreck by rules derived from these laws of storms, is a witness to the sagacity and benevolence of Redfield. Other writers on the laws of storms, especially Reid and Piddington, have lent important aid in establishing rules for navigators, until it is now easy for the mariner by the direction in which the gale strikes his ship, to determine his position in the storm, and the course he must steer in order to escape from its fury. Nor are testimonies wanting of the successful application of these rules. The most accomplished navigators (we might instance particularly Commodores Rodgers and Perry, and Commander Glynn, of the U. S. Navy) have testified that within their knowledge and in some cases within their own observation, many ships have owed their deliverance from the perils of shipwreck to a faithful observance of the rules derived from Redfield's theory of storms.

In no department, perhaps, of the studies of nature have mankind been more surprised to find things governed by fixed laws, than in the case of the winds. It is now rendered in the highest degree probable, that every breeze that blows is a part of some great system of aerial circulation and helps to fulfill some grand design. "Inconstant as the winds" has long been a favorite expression to denote the absence of all uniformity or approach to fixed rules; but the researches of the meteorologists of our times, force on us the conclusion that the winds, even in the violent forms of hurricanes and tornadoes, are governed by laws hardly less determinate than those which control the movements of the planets.

It has been often noticed in the history of science and the arts, that great discoveries and inventions spring forth simultaneously from different independent sources. Thus the discovery of oxygen gas, the greatest single discovery in chemistry, was made almost at the same moment by Priestley in England and Scheele in Sweden; and the method of fluxions, or the infinitesimal calculus, was invented at nearly the same time by Newton and Leibnitz. Such discoveries and inventions are the true resultant of innumerable forces, which at that moment, and never until then since the origin of time, all conspired. It is remarkable that the idea that great storms are progressive whirlwinds was, for the first time, embraced nearly at the same instant by Redfield and Dové, although the conclusion was arrived at by totally different methods of investigation. Mr. Redfield says in a note to his paper on the Cuba hurricane, published in 1846, that it was not until seven years after the publication of his theory of the rotary and progressive character of storms, that he became acquainted with the suggestions and opinions of Col. Capper, and with the particular views and elucidations published by Professor Dové in his paper on Barometric Minima found in Poggendorff's Annalen for 1828. To all who were personally acquainted with Redfield, it would be quite unnecessary to adduce any other evidence than his simple declaration, of the perfectly original and independent character of his theory of the laws of storms. But we might refer to the circumstances under which it was conceived, when he was far removed from all libra-

ries, and all intercourse with the scientific world; and as respects Dové, in particular, whose essay was communicated to the public in 1828, it may be said, that at that period there was scarcely a copy of Poggendorff's Annalen, in which Dové's essay appeared, in the United States; and being in the German language, nothing could be more improbable than that its contents were then known to Redfield. In 1838, our friend found to his great joy a most able ally in Col. Reid of the Royal English Engineers, then stationed in the island of Barbadoes. The earliest inquiries of Col. Reid were based on a violent hurricane, which occurred in that island in the year 1831. Searching for accounts of previous storms, he met with nothing satisfactory until he fell in with Redfield's earliest paper respecting the September gale of 1821, published in the American Journal of Science. With the view of testing Redfield's doctrines, he submitted to the closest scrutiny the records which the Barbadoes storm had left of its ravages,—an investigation which ended in a perfect conviction that this storm was a progressive whirlwind. A friendly correspondence was shortly afterwards opened between these two congenial spirits, which resulted in an intimacy unbroken except by the hand of death. Commodore Perry, in the recent Report of his Japan Expedition, thus expresses himself in an introductory note to Mr. Redfield's Essay (the latest of his published works) on the Cyclones of the Pacific, addressed to Commodore Perry, and forming a part of his volume. "It was my good fortune (says the Commodore) to enjoy, for many years, the friendly acquaintance of one as remarkable for modesty and unassuming pretensions, as for laborious observation and inquiry after knowledge. To him and to Gen. Reid of the Royal Engineers of England (now governor of Malta) are navigators mainly indebted for the discovery of a law which has already contributed, and will continue to contribute, greatly to the safety of vessels traversing the ocean. It is true that subsequent writers have furnished additional information on this subject; but to Redfield and Reid should be ascribed, the credit of the original discovery of this undeniable law of nature and its application to useful purposes; and there can be nothing more beautiful, as illustrative of the character of these two men, than the fact, well known

to myself, that notwithstanding their simultaneous observations and discoveries, in different parts of the world, neither claimed the slightest merit over the other, but each strove to give to his co-worker in research the meed of superior success in the great object of their joint labors; and thus, without ever meeting, a strong friendship was formed between them, growing out of congenial aspirations for an honorable fame, and mutual admiration of the generous and enlightened views exhibited by each other; and this ennobling feeling was kept alive to the last by friendly correspondence."

The idea of whirlwinds is indeed much older than Redfield or Reid, being as old as the writings of the Psalmist and the Prophets; and we safely admit further, that the doctrine of ocean gales being sometimes of a rotary character, had been hinted at by several writers, as hints of such a principle as gravitation had long preceded the investigations of Newton; but the honor of having established, on satisfactory evidence, the rotary and progressive character of ocean storms, and determining their modes of action or laws, it is due alike to the memory of the departed, and to our country's fame, to claim for WILLIAM C. REDFIELD.

Back of the laws that govern these ocean gales, as first determined by Redfield and confirmed by Dové, Reid, Piddington, Thom, and other well known writers, lies a more profound inquiry, How are these laws themselves to be accounted for? What sets the storm in motion, and gives it the whirlwind character, and at the same time carries it forward, and in so definite a path? What makes it revolve always from right to left on the north side of the equator, and from left to right on the south side? Why does its violence increase towards the centre of the storm, and why is its force there so tremendous? Laws, it must be remembered are facts, and merely express the modes in which nature acts: they are themselves phenomena to be accounted for. To which of the ultimate causes of physical phenomena is their origin, in the present case, to be traced? Is it heat? Is it electricity? Is it gravity? Is it connected in some way with the grand system of planetary motion? Questions of this kind were pressed on Mr. Redfield from various sources by those who assailed his theory. At first he declined any attempts at their solution. He claimed that the whirlwind character of

storms, and the laws which he had assigned to them, are matters of fact, as established not only by himself, but also by Reid, Milne, Dové, and Piddington; that never having attempted to establish a theory of winds, nor the origin or first cause of storms, he had no occasion to go into these inquiries, but had long held the proper inquiry to be, *What are storms?* not *How are storms produced?* He however incidentally, at different times, indicated his opinions on the ultimate causes of storms. Electricity, Redfield entirely rejected as an agent in the production of winds and storms, considering its presence and development rather as a consequence than as a cause of atmospheric changes. To heat he assigned only a limited and local effect, denying its agency in producing either the great and established movements of the atmosphere, or the extraordinary commotions which constituted the chief objects of his study, hurricanes and tempests. But he considered what he called the "dynamics of the atmosphere," as connected with and resulting from the diurnal and annual motions of the earth. While, from the first, I have heartily embraced Redfield's doctrine that ocean gales are progressive whirlwinds, and have further fully believed that he had established their laws or modes of action on an impregnable basis, a regard to truth and candor obliges me to say, that I have never been a convert to his views respecting the ultimate causes of storms, especially so far as he assigned for these causes what he denominates the "diurnal and orbitual motions of the earth," but his notions on this point have always appeared to me unsatisfactory. Nor, while I have been impressed with the belief that *heat* is, in general, by far the most influential of all natural agents in destroying the equilibrium of the atmosphere, and of causing its motions, both in established currents, as the trade winds and the monsoons, and in its violent commotions, as in hurricanes and tornadoes, yet I am compelled to think that but little progress has yet been made in determining its *modus operandi*, or in tracing the *connection* between changes of temperature and the actual phenomena of winds and storms:—why, for example, the Atlantic gales originate where they do, in the tropical regions—why they first pursue a path to the northwest as far as the latitude of 30°, and then gracefully wheel in parabolic curves towards the northeast, and pursue this course for the re-

mainder of their way—why they revolve on their axes and always in one direction—whence they acquire so tremendous a force, especially towards the central parts—why the barometer is so low in the center and so high on the margin of the storm. These and various other points connected with the whirlwind character of storms, seem to me to have met hitherto with but a partial and doubtful solution. The laws constitute the true theory of storms: the rest is yet hypothesis.

Various writers have severally displayed great ingenuity and profound knowledge of atmospheric phenomena, in their endeavors to solve these problems, but with respect to the causes which lie back of the laws of storms, we still remain to a great degree in ignorance. Each of the combatants appears to me to be more successful in showing the insufficiency of the other's views, than in establishing his own. With respect to him who is more particularly the subject of my remarks, whose logical powers I have always admired, I have almost regretted that he did not adhere to the ground he originally took, namely, that he had not undertaken to explain the reason *why* the winds blow, but only to show *how* they blow. So far was matter of fact: all beyond was hypothesis. His facts are impregnable: his hypothesis doubtful. The conclusions derived legitimately from these facts constitute the laws of storms; and being, as we believe, like the other laws of nature immutable, the name indissolubly associated with their discovery, acquires a fame alike imperishable. Redfield might therefore have safely stopped where Newton stopped. "Newton (says one of his biographers) stopped short at the last fact which he could discover in the solar system—that all bodies were deflected to all other bodies, according to certain regulations of distance and quantity of matter. When told that he had done nothing in philosophy; that he had discovered no cause; and that, to merit any praise, he must show how this deflection was produced; he said, he knew no more than he had told them; that he saw nothing causing this deflection; and was contented with having described it so exactly, that a good mathematician could now make tables of the planetary motions, as accurate as he pleased, and hoped in a few years to have every purpose of navigation and philosophical curiosity completely answered."

Various other contributions to science of our departed friend must, for want of space, be passed by with hardly a notice. Such are his published meteorological essays*—his reports of meteorological observations, which contain many original hints of much value—his paper on the currents of the Atlantic—and his researches in geology, which occupied much of his attention during the latter years of his life—all of which speak the skilful observer, the judicious philosopher, the lover of science, the lover of his country and of his kind. His meteorological researches, although they engrossed a large share of the hours he could redeem from the urgent claims of business, did not prevent his taking a strong interest in other branches of science. He attentively watched the progress of knowledge in various departments, but Geology had for him special attractions. His powers of observation were early employed, even in his pedestrian tour to Ohio in 1810, in noting facts which appeared to him then to be unaccounted for, but which the progress of the science has since fully explained. In the meetings of the American Association he was an attentive listener to the geological papers, and frequently took part in the discussions which they called forth, exhibiting a thorough acquaintance with the subjects under consideration. The phenomena of the drift period, as evincive of glacial action in various forms had deeply interested him; and he had collected, and closely studied, the shells of recent species which, in the vicinity of New York are found beneath the deposits of drift. His published geological papers, however, relate chiefly to the sandstones of Connecticut and New Jersey, particularly to their fossils, their ripple-marks, and their rain-drops. His residence in early life was within sight of the extensive quarries of this kind of sandstone, at Portland, Connecticut, and his frequent visits afterwards to that region, afforded him opportunity for close observation. In December, 1836, his son Mr. John H. Redfield, who inherits much of the scientific taste of his father, described† some of the fossil fishes from this locality, and showed that their structural affinities indicated for the so-called "New Red Sandstone" a higher position than had previously been assigned to it. Mr. Redfield pursued the track thus

* Originally prepared for Blunt's Coast Pilot.

† Annals Lyc. Nat. History, New York, vol. iv.

opened by his son, and published, in the American Journal of Science, descriptions of several new species of Icthyolites. The last paper which he read before the American Association was upon the Geological Age of the Sandstones of Connecticut and New Jersey, and the cotemporaneous deposits in Virginia and North Carolina. He proposed for them the denomination of the *Newark Group*, and showed that the Ichthyolites contained in them pointed unerringly to the Jurassic period. In the course of these investigations he had given close study to the subject of Fossil Fishes, and had formed a collection of them, probably unequalled in this country, with special reference to a contemplated monograph of the Ichthyolites of the Newark Group.

In 1839, Yale College conferred on Mr. Redfield the honorary degree of Master of Arts, and the enlarged sphere in which his labors for the promotion of science and the good of his fellow men, were known and appreciated, was evinced by his election into many learned societies in his own and foreign countries.

Three distinguishing marks of the true philosopher met in William C. Redfield—originality to devise new things; patience to investigate; and logical powers to draw the proper conclusions. The impress of his originality he left, in early life, upon the village where he resided; he afterwards imprinted it still deeper on his professional business, as naval engineer; and most of all on his scientific labors, his observations, and his theories. "Patient thought" was the motto of Newton, and in this attribute, Redfield was eminently distinguished. In collecting facts bearing upon his main purpose, and in submitting them to severe and long continued comparison, he has illustrated this quality in its highest forms, as his laborious investigations of the phenomena of hundreds of storms, most fully evince. Originality to invent without patience to investigate, leads to hasty and wild speculations; but united they lay the deep foundations for a severe logic. His powers of reasoning have always appeared to me to be of high order, and he has been fitly characterized by another eminent writer* on the laws of storms, as the "clear-headed" Redfield. Opinions which he had thus formed, after an extensive and patient investigation of the facts, and a severe process of reasoning, he held with

* Reid.

great tenacity. But though firm, he was not obstinate. *Obstinacy* we define to be an unyielding adherence to our opinions because we have adopted them: *firmness*, a similar adherence to our opinions, because we believe them to be right.

Few men have given more signal proofs of an original inherent love of knowledge. Whether we contemplate the apprentice-boy after the toils of the day, seeking for knowledge by the dim light of an open fire; or the father of a young family, through dark scenes of domestic affliction and mournful bereavements, still adding largely year by year to his intellectual stores; or the man of business in the whirl of the great metropolis, loaded with onerous and responsible cares, giving every interval of leisure, and the seasons chiefly employed in pleasure or repose to the study of the laws of nature; or if permitted, as has been my privilege, to be a guest at the house fitted up to be the retreat of his old age, we see the library, the collections of natural history, the many sources of high mental enjoyment, which in the period gained at last of ease and affluence, distinguish the different apartments of his dwelling; or finally whether we call to mind the ever increasing interest with which he attended the meetings of the American Association for the Advancement of Science, and the delight which he experienced in the society of learned men, we observe in all, a mind in love with truth, ever searching and ever expanding. In society he was courteous, sincere, upright, and benevolent; in his family, tender, affectionate, wise in counsel and pure in example; in all his walk and conversation, and especially in the church of God, a devout and humble christian.

As the evening of life was passing thus serenely, it hastened to a peaceful close. Mr. Redfield's health had been generally good during his later years, and had seemed particularly so in the early part of the winter which proved his last. On the first of January, he made his usual calls on his friends, and the cheerfulness and vivacity of his manners and healthful expression, were never more remarkable. Near the last of January he was seized with alarming symptoms, which indicated effusion in the chest. His disease made rapid and sure progress. The last book which had engaged his attention previous to his illness was Dr. Kane's recent Narrative of his Arctic Expedition, and his own feverish

dreams, during the earlier nights of his sickness, were confusedly identified with the toils, the difficulties, and the sufferings of that heroic commander and his brave companions. With a general tendency to delirium were mingled intervals of calmness, and throughout his illness his countenance would light up with the smile of affection, as he recognized the relations and friends around him. From the first he entertained but slight hopes of recovery; but as the crisis drew near, his mind was at peace, and in calm resignation to the will of his Maker, and in the full exercise of christian faith, he gently breathed his last on the morning of February 12, 1857.

Happy if we who have so long journeyed with him in the delightful walks of science, may enjoy an evening as serene, and find its close as peaceful.

List of the published papers of the late WILLIAM C. REDFIELD.

1. Sketch of the Geographical Route of a great Railway, by which it is proposed to connect the Canals and navigable waters of the States of New York, Pennsylvania, Ohio, Indiana, Illinois, Missouri, and the Michigan, North West, and Missouri Territories, opening thereby a free communication at all seasons of the year between the Atlantic States and the great valley of the Mississippi. Pamphlet, published by G. & C. & H. Carvill, New York, 1829.

A second edition of the above, with an appendix of much additional matter, was published by the same house in 1830.

2. Remarks on the prevailing storms of the Atlantic Coast of the North American States. American Journal of Science, vol. xx, p. 17. April, 1831.

3. List of Steamboat Explosions which have occurred in the United States, with some remarks on the same. Am. Journ. Sci., xx, 336. July, 1831.

4. On the supposed collapse of Steam-boilers, and the means of preventing explosions. Amer. Journ. Sci., xxi, 190. Oct. 1831.

5. Note on the Hurricane of August, 1831. N. Y. Journal of Commerce, Sept 28, 1831. Copied in Am. Jour. Sci., xxi, 191, Oct. 1831.

6. Facts and Suggestions relating to the New York and Albany Railroad. Pamphlet, New York, 1832.

7. Notice of American Steamboats. Amer. Journ. Sci., xxiii, 311, Jan. 1833.

8. Observations on the Hurricanes and Storms of the West Indies and the Coast of the United States. Blunt's American Coast Pilot, 12th edition, p. 626, July, 1833, and in subsequent editions; also in Amer. Jour. Sci., xxv, 114, Oct. 1833; translated in Bibl. Univ. de Genève, i, 412, 1834.

An Abstract of the above under the title of "Monitions and Instructions for vessels navigating on the western side of the Atlantic" is found in Purdy's Memoir upon the Atlantic Ocean, 10th edition, 1853, p. 303.

9. Summary Statements of some of the leading Facts in Meteorology. Amer. Journ. Sci., xxv, 122, Oct. 1833. Originally prepared for the American edition of "Million of Facts," published in New York, 1833. It constitutes the new matter under the head of "Atmospheric and Aerial Phenomena" in that work. Some copies have been circulated in pamphlet form under the title of "Facts in Meteorology."

10. Report of the Board of Examiners appointed by the Connecticut River Steam Boat Company to enquire into the Causes of the Explosion of the Steam Boat New England. Published by the Steam Boat Company. Dec. 1833.

11. Synopsis of a Meteorological Journal kept in the city of New York during the years 1833 and 1834. Report of the Regents of the Univ. of State of N. Y. for 1835, p. 183; Amer. Journ. Sci., xxviii, 154, April, 1835.

12. On the Evidence of certain Phenomena in Tides and Meteorology, (In reply to Notes of an Observer [Mr. Espy]). Journ. Franklin Institute, Phil., xv, 372, June, 1835; Amer. Journ. Sci., xxviii, 310, July, 1835.

13. On the Gales and Hurricanes of the Western Atlantic. London Nautical Magazine, v, 199, April, 1836; U. S. Naval Magazine, i, 301, July, 1836; Amer. Journ. Sci., xxxi, 115, Oct. 1836.

14. On the Whirlwind character of certain Storms, (In reply to Mr. Espy's No. 3, in a series of Meteorological Essays in Journ. of Franklin Institute). Journ. Franklin Institute, xix, 112, Feb. 1837.

15. Remarks on the supposed connection of the Gulf Stream with opposite currents. U. S. Naval Magazine, ii, 243, May, 1837; Journ. Franklin Institute, xix, 384, May, 1837; Blunt's Amer. Coast Pilot, 13th edition, p. 666, June, 1837, and in subsequent editions; American Journ. Sci., xxxii, 349, July, 1837.

16. Synopsis of a Meteorological Journal kept in the City of New York, during the years 1835 and 1836; reported to the Albany Institute. Report of Regents of Univ. of State of N. Y. for 1837, p. 214, March, 1837.

17. Cursory Remarks and Suggestions on various topics in Meteorology, by an Amateur Observer. Blunt's Amer. Coast Pilot, 13th ed., p. 689, and subsequent editions, June, 1837.

The same under the title of "Meteorological Sketches, by an Observer." Amer. Jour. Sci., xxxiii, 50, 261, Oct. 1837 and Jan. 1838; U. S. Naval Mag., ii, 392, 1837.

18. Some account of two visits to the Mountains in Essex Co., N. York, in the years 1836 and 1837; with a sketch of the northern sources of the Hudson. Am. Journ. Sci., xxxiii, Jan. 1838; Family Magazine, N. Y., v, 345.

19. Notice of Fossil Fishes in Virginia. Amer. Jour. Sci., xxxiv, 201, April, 1838.

20. Synopsis of Meteorological Journal kept in the City of New York for the year 1837, including the average results of the last five years. Report of Regents, 1838 or 1839; Am. Journ. Sci., xxxiv, 373, July, 1838.

21. Letter to Lieut. James Hoskin, R. N., Commander of the Steamship Great Western, on the speed of Steamboats. N. Y. Journal of Commerce, Aug. 8, 1838; London Nautical Magazine, 1838, p. 673; Jameson's Journal, Feb., April, 1838.

22. On the courses of Hurricanes, with notices of the Typhoons of the China Sea, and other Storms. Amer. Journ. Sci., xxxv, 201, Jan. 1839; London Nautical Magazine, 1839, p. 1, Jan. 1839.

23. Genealogy of the Redfield Family in the United States. Printed for private circulation, March, 1839.

24. Some Account of violent columnar Whirlwinds which appear to have resulted from the action of large circular Fires, with Remarks on the same. (Read before the Connecticut Academy of Arts and Sciences, Jan. 22, 1839.) Amer. Jour. Sci., xxxvi, 50, April, 1839; Bibliothèque Univ. de Genève, 1840, xxviii, 432.

25. Additional Facts relating to the Raleigh's Typhoon of August 5th and 6th, 1835, in the China Sea. Amer. Journ. Sci., xxxvi, 59, April, 1839; London Nautical Magazine, 1839, p. 461.

26. Letter to the Secretary of Treasury of U. S. on Steamboat Explosions and their preventions, dated Dec. 26, 1838. Congressional Document, 25th Congress, 3d Session, House of Reps., Doc. No. 21, 1839; London Nautical Magazine, 1839, p. 617, 681 and 813.

27. Remarks on Mr. Espy's Theory of Centripetal Storms, especially his positions relative to the storm of Sept. 3d, 1821, with some notice of his examinations of other storms. Journ. Franklin Institute, xxiii, 323, 363, May and June, 1839.

28. Further notice of Mr. Espy's examination of Storms. Journ. Franklin Inst., xxiv, 1, July, 1839.

29. Account of the Circular Storm of Dec. 1839. Journ. of Commerce, Jan. 6, 1840; London Nautical Magazine, 1840, 424.

30. On the Causes of Steamboat Accidents and the practical means of preventing their occurrence. (Communicated by request through Capt. J. W. Pringle, R. E., to the Commissioners on that subject appointed by the English Government. Received too late for the Report of the Commissioners), but published here in "Appendix to a Memorial of Proprietors and Managers of American Steam-vessels on the impolicy and injustice of certain enactments contained in the law relating to steamboats." Jan. 1840.

31. Abstracts of Meteorological Observations made at St. John's, Newfoundland, and at Canton in China, with some notice of the Half-yearly Inequalities of Atmospheric Distribution which appear in these observations. Am. Jour. Sci., xxxviii, 265, April, 1840.

32. Synopsis of a Meteorological Journal kept in the City of New York for the years 1838 and 1839, including also the mean results of the last seven years. Report of the Regents of the University of State of N. Y., 1840; Am. Journ. Sci., xxxviii, 323, April, 1840.

33. Short Notices of American Fossil Fishes. (Read before the Yale Natural History Society.) Am. Jour. Sci., xli, 24, July, 1841.

34. Five Letters to Commodore Perry on the means of National Defence. N. Y. Journal of Commerce, July, 1841.

35. Remarks relating to the Tornado which visited New Brunswick in the State of New Jersey on the 19th June, 1835, with a plan and schedule of the prostrations observed on a section of its track. London, Ed. and Dub. Phil. Mag. and Jour. Sci., xviii, 20, Jan. 1841; Am. Jour. Sci., xli, 69, July, 1841; Jour. Frankl. Inst., xxviii (or 3d series ii), 40, July, 1841.

36. Observations on the Storm of Dec. 15th, 1839, with a Map showing the direction of the wind at noon of that day, as observed at various places. (Read before the Am. Phil. Soc., Jan. 15, 1841.) Lond., Ed. and Dubl. Phil. Mag., xvii, 17, July, 1841; Am. Jour. Sci., xlii, 112, Jan. 1842; Trans. Am. Phil. Soc., viii, new series, 77, 1843.

37. Extract of a letter to Sir J. F. W. Herschel. Report of 10th meeting of British Assoc. for Adv. of Science, 1841, p. 40, 1841.

38. Reply to Dr. Hare's Objections to the Whirlwind Theory of Storms. Am. Jour. Sci., xlii, 299, April, 1842; Lond., Ed. and Dubl. Phil. Mag., xx, 353, May, 1842.

39. Reply to Dr. Hare's Further Objections relating to Whirlwind Storms, with some evidence of the whirling action of the Providence Tornado of August, 1838. Am. Jour. Sci., xliii, 250, Oct. 1842; latter portion of the article also in Amer. Repertory of Arts and Sci., iii, 81, March, 1841; also in Jour. Frank. Inst., new series, iv, 252, Oct. 1842; first portion of article also in Lond., Ed. and Dubl. Phil. Mag., xxi, Suppl. 481, Dec. 1842; latter portion of article also in same, xxii, 38, Jan. 1843.

40. Notice of newly discovered Fish-beds and a Fossil Foot-mark in the Red Sandstone Formation of New Jersey. Am. Jour. Sci., xliv, 134, Jan. 1843.

41. Notice of Dr. Hare's Strictures on Prof. Dove's Essay on the Law of Storms Am. Jour. Sci., xliv, 384, April, 1843; Jour Franklin Inst. for 1844, p. 384.

42. Remarks on Tides and the prevailing Currents of the Ocean and Atmosphere. (Read before Amer. Phil. Soc. at its centennial meeting, May 27th, 1843.) Am. Jour. Sci., xlv, 393, Oct. 1843; London Nautical Magazine, 1843, 655.

43. On the drift Ice and Currents of the North Atlantic, with a Chart showing the observed positions of the Ice at various times. Am. Jour. Sci., xlviii, 373, April, 1845; London Nautical Magazine, 1845, p. 298, 353; Blunt's Memoir on the Dangers and Ice of the North Atlantic.

44. Letters to the U. S. Board of Navy Commissioners, being replies to their circular asking information relative to Steam Navigation applicable to government purposes. Jour. Frankl. Inst., new series, x, 361, and xii, 1, June, July and Aug. 1846.

45. On three several Hurricanes of the American Seas, and their relation to the Northers so called of the Gulf of Mexico and the Bay of Honduras, with Charts illustrating the same. Am. Jour. Sci., new series, i, 1, 153, 333, ii, 162, 311, Jan., March, May, Sept. and Nov. 1846.

46. Effects of the Earth's Rotation upon Falling Bodies, and upon the Atmosphere. Am. Jour. Sci., new series, iii, 283, March, 1847.

47. Remarks on a Letter from R. N. Shufeldt of U. S. Ship Marion to E. and G. W. Blunt, relative to a Hurricane encountered by Ship Marion, Sept. 1848. London Nautical Magazine, 1849, p. 39.

48. On some Fossil Remains from Broome Co., N. Y. Proceedings of Am. Assoc. for Adv. of Science, 2d Meeting, 1849, (at Cambridge,) p. 255.

49. The Law of Storms and its penalties for neglects. N. Y. Jour. of Commerce, June 19, 1850; London Nautical Magazine, 1850, p. 470; Bermuda Royal Gazette, July 16, 1850; N. Y. Courier and Enquirer.

50. On the apparent necessity of revising the received systems of Dynamical Meteorology. Proc. Am. Assoc. for Adv. of Sci., 4th Meeting, (New Haven,) p. 366, 1850.

51. On the Post-Permian Date of the Red Sandstone Rocks of New Jersey and the Connecticut Valley, as shown by their Fossil Remains. Proc. Am. Assoc. for Adv. of Science, 5th Meeting, (Cincinnati,) p. 45, May, 1851.

52. On the Fossil Rain-marks found in the Red Sandstone Rocks of New Jersey and the Connecticut Valley, and their authentic character. Proc. Am. Assoc. for Adv. of Science, 5th Meeting, (Cincinnati,) p. 72, May, 1851.

53. On the value of the Barometer in navigating the American Lakes. Proc. Am. Assoc. for Adv. of Science, 7th Meeting, (Cleveland,) p. 54, 1853; Wells's Annual of Scientific Discovery for 1854, p. 200.

54. A storm-track of Seven Thousand Miles. Annals of Science, Cleveland, vol. ii, p. 47, 1854.

55. Cape Verde and Hatteras Hurricane and other Storms, with a Hurricane Chart. Proc. Amer. Assoc. for Adv. Sci., 8th Meeting, (Washington,) p. 208, 1854. This paper and the preceding are abstracts of the following.

56. On the first Hurricane of September, 1853, in the Atlantic, with a Chart, and Notices of other Storms (Cape Verde and Hatteras Hurricane). Am. Jour. Sci., new series, xviii, 1, 176, July and Sept. 1854; London Nautical Mag., 1854, p. 466, 526, 597, Sept., Oct., Nov. 1854.

57. On the Storm of October 7th, 1854, near the coast of Japan, and the Conformity of its progression with other Cyclones. Proc. Am. Assoc. for Adv. of Sci., 9th Meeting, (Providence,) Aug. 1855, p. 183.

58. On the relations of the Fossil Fishes of the Sandstone of Connecticut and other Atlantic States to the Liassic and Oolitic Periods. Read before the American Assoc. for Advancement of Science, Albany, Aug. 26, 1856. Am. Jour. Sci., new series, xxii, 357, Nov. 1856; Proc. Am. Assoc. for Adv. of Sci., 10th Meeting, Albany, p. 180, 1857.

59. On the Spirality of Motion in Whirlwinds. Am. Jour. Sci., new series, xxiii, 23, Jan. 1857.

60. *Notes* attached to a Communication "On the Avoidance of the violent portions of Cyclones, with notices of a Typhoon at the Bonin Islands," (by John Rodgers, Commander U. S. N., and Anton Schönborn, Assist. Ast.) Am. Jour. Sci., new series, xxiii, 205, March, 1857.

61. On Pacific Cyclones. Am. Jour. Sci., xxiv, 21, July, 1857. An abstract of the following.

62. Observations in relation to the Cyclones of the Western Pacific, embraced in a Communication to Commodore Perry. Perry's Japan Expedition, ii, 335, July, 1857.