THE

USES OF ASTRONOMY.

A DISCOURSE DELIVERED AT ALBANY ON THE 28TH OF AUGUST, 1856, ON OCCASION OF THE INAUGURATION OF THE DUDLEY OBSERVATORY.

BY

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TO

MRS. BLANDINA DUDLEY,

TO THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,

TO THE REGENTS OF THE UNIVERSITY OF THE STATE OF NEW YORK,

AND TO

THE CITIZENS OF ALBANY, GENERALLY,

THIS DISCOURSE

DELIVERED ON THEIR INVITATION AND IN THEIR PRESENCE,

AND PUBLISHED AT THE REQUEST OF THE COMMITTEE OF ARRANGEMENTS FOR THE INAUGURATION OF THE DUDLEY OBSERVATORY, IS, WITH THE BEST WISHES FOR THE COMPLETE SUCCESS OF THAT NOBLE ENTERPRISE,

RESPECTFULLY DEDICATED BY

EDWARD EVERETT.

BOSTON, September, 1856.

ORATION.

Fellow-citizens of Albany, —

Assembled as we are under your auspices in this ancient and hospitable city, for an object indicative of a highly advanced stage of scientific culture, it is natural in the first place to cast an historical glance at the past. It seems almost to surpass belief, though an unquestioned fact, that more than a century should have passed away, after Cabot had discovered the coast of North America for England, before any knowledge was gained of the noble river on which your city stands, and which was destined by Providence to determine in after-times the position of the commercial metropolis of the continent. It is true that Verazzano, a bold and sagacious Florentine navigator in the service of France, had entered the Narrows in 1524, which he describes as a very large river, deep at its mouth, which forced its way through steep hills to the sea. But though he, like most of the naval adventurers of that age, was sailing westward in search of a shorter passage to India, he left this part of the coast without any attempt to ascend the river; nor can it be gathered from his narrative that he believed it to penetrate far into the interior.

Near a hundred years elapsed, before that great thought acquired form and substance. In the Spring of 1609, the heroic but unfortunate Hudson, one of the brightest names in the history of English maritime achievement, but then in the employment of the Dutch East India Company, in a vessel of eighty tons, bearing the very astronomical name of the "Half-moon," having been stopped by the ice in the polar sea in the attempt to reach the East by the way of Nova Zembla, struck over to the coast of America in a high northern latitude. He then stretched down south-westwardly to the entrance of Chesapeake Bay, (of which he had gained a knowledge from the charts and descriptions of his friend, Capt. Smith,) — thence returning to the North, entered Delaware Bay, — standing out again to sea arrived on the 2d of September in sight of the "high hills" of Neversink, pronouncing it "a good land to fall in with, and a pleasant land to see," and on the following morning, sending his boat before him to sound the way, passed Sandy Hook, and there came to anchor, on the third of September, 1609; two hundred and forty-seven years ago, next Wednesday. What an event, my friends, in the history of American population, enterprise, commerce, intelligence, and power, — the dropping of that anchor at Sandy Hook!

Here he lingered a week, in friendly intercourse with the natives of New Jersey, while a boat's company explored the waters up to Newark Bay. And now the great question. Shall he turn back like Verazzano, or ascend the stream? Hudson was of a race and in an employ, not prone to turn back, by sea or by land. On the 11th of September he raised the anchor of the "Half-moon," passed through the Narrows, beholding on both sides "as beautiful a land as one can tread on;" and floated cautiously and slowly up the noble stream, the first ship that ever rested on its bosom. He passed the Palisades, nature's dark basaltic Malakoff; forced the iron gateway of the Highlands, and anchored on the 14th, near West Point; swept onward and upward the following day by grassy meadows and tangled slopes, hereafter to be covered with smiling villages; — by elevated banks and woody heights, the destined site of future towns and cities, — *tot egregias urbes*, — of Newburg, Poughkeepsie, Catskill; — on the evening of the 15th arrived opposite "the mountains which lie from the river side," where he found "a very loving people and very old men;" and the day following reached the spot, hereafter to be honored by his own illustrious name. One more day wafts him up between Schodac and Castleton, and here he landed and passed a day with the natives, — greeted with all sorts of barbarous hospitality, — the land "the finest for cultivation he ever set foot on," the natives so kind and gentle that, when they found he would not remain with them over night, and feared that he left them, — poor children of nature, — because he was afraid of their weapons, he, whose quarter-deck was heavy with ordnance, they "broke their arrows in pieces, and threw them in the fire." On the following morning, with the early flood-tide, on the 19th of September, 1609, the Halfmoon "ran higher up two leagues above the Shoals," and came to anchor in deep water, near the site of the present city of Albany. Happy, if he could have closed his gallant career, on the banks of the stream which so justly bears his name, and thus have escaped the sorrowful and mysterious catastrophe which awaited him in the Arctic waters, the next year!

But the discovery of your great river and of the site of your ancient city is not the only event, which renders the year 1609 memorable in the annals of America and the world. It was one of those years, in which a sort of sympathetic movement toward great results unconsciously pervades the races and the minds of men. While Hudson was exploring this mighty river and this vast region for the Dutch East India Company, Champlain, in the same year, carried the lilies of France to the beautiful lake which bears his name on your northern limits; — the languishing establishments of England in Virginia were strengthened by the second charter granted to that colony; — the little church of Robinson removed from Amsterdam to Leyden, from which, in a few years, they went forth, to lay the foundations of New England on Plymouth Rock; — the seven United Provinces of the Netherlands, after that terrific struggle of forty years, (the commencement of which has just been embalmed by an American historian in a record worthy of the great event,) wrested from Spain the virtual acknowledgment of their independence in the Twelve Years' truce; — and James the First, in the same year, granted to the British East India Company their first permanent charter; corner-stone of an empire destined in two centuries to overshadow the East.

One more incident is wanting to complete the list of the memorable occurrences which signalize the year 1609, and one most worthy to be remembered by us on this occasion. Contemporaneously with the events which I have enumerated, — eras of history, dates of empire, the starting point in some of the greatest political, social, and moral revolutions in our annals, an Italian astronomer, who had heard of the magnifying glasses which had been made in Holland by which distant objects could be brought seemingly near, caught at the idea, constructed a telescope, and pointed it to the heavens. Yes, my friends, in the same year in which Hudson discovered your river and the site of your ancient town, in which Robinson made his melancholy Hegira from Amsterdam to Leyden, Galileo Galilei, with a telescope, the work of his own hands, discovered the phases of Venus and the satellites of Jupiter; and now, after the lapse of less than two centuries and a half, on a spot then imbosomed in the wilderness, the covert of some of the least civilized of all the races of men, we are assembled, descendants of the Hollanders, descendants of the Pilgrims, in this ancient and prosperous city, to inaugurate the establishment of a first class Astronomical Observatory.

One more glance at your early history. Three years after the landing of the Pilgrims at Plymouth, (for I delight to trace these kindly synchronisms,) Fort Orange was erected, in the centre of what is now the business part of the city of Albany, and a few years later, the little hamlet of Beverswyck began to nestle under its walls. Two centuries ago, my Albanian friends, this very year, your forefathers assembled, not certainly to inaugurate an observatory, but to lay the foundations of a new church in the place of the rude cabin which had hitherto served them in that capacity. It was built at the intersection of Yonker's and Handelaar's, better known to you as State and Market streets. Public and private liberality coöperated in the important work. The authorities at the fort gave fifteen hundred guilders; — the Patroon of that early day, with the liberality coeval with the name and the race, contributed a thousand; — while the inhabitants, for whose benefit it was erected, whose numbers were small and their resources smaller, subscribed twenty beavers, "for the purchase of an oaken pulpit in Holland." Whether the largest part of this subscription was bestowed by some liberal benefactress, tradition has not informed us. It has however informed us, as I learned a few hours since from Mr. Brodhead, that the corner-stone of the little church was laid by the Rev. Rutger Jacobsen; and that his daughter married Jan Jansen Bleecker, from whom is lineally descended Mrs. Blandina Bleecker Dudley, to whom we are so largely indebted for this day's celebration.

Nor is the year 1656 memorable in the annals of Albany alone. In that same year your imperial metropolis, which had then recently been incorporated as a city by the name of New Amsterdam, was first carefully surveyed by official authority, and found to contain one hundred and twenty houses and one thousand inhabitants.* In eight years more

* These historical notices, relative to the discovery of the river by Hudson, and the foundation of Albany, are for the most part abridged from Mr. Brodhead's excellent history of New York.

New Netherland becomes New York; Fort Orange, with its dependent hamlet, assumes the name of Albany; — a century of various fortune succeeds, — the scourge of French and Indian war is rarely absent from the land, — every shock of European policy vibrates with electric rapidity across the Atlantic, but the year 1756 finds a population of three hundred thousand in your growing province. Albany, however, may still be regarded almost as a frontier settlement. Of the twelve counties into which the province was divided a hundred years ago, the county of Albany comprehended all that lay north and west of the city; and the city itself contained but about three hundred and fifty houses.

One more century; another act in the great drama of empire; another French and Indian war beneath the banners of England; a successful revolution, of which some of the most momentous events occurred within your immediate neighborhood; a union of States; a constitution of federal government; your population carried to the St. Lawrence and the great Lakes, and their waters poured into the Hudson; your territory covered with a network of canals and railroads, filled with life, and action, and power, with all the works of peaceful art and prosperous enterprise, with all the institutions which constitute and advance the civilization of the age, its population exceeding that of the Union at the date of the Revolution, your own numbers twice as large as those of the largest city of that day, you have met together, my friends, just two hundred years since the erection of the little church of Beverswyck, to dedicate a noble temple of science, and to take a becoming public notice of the establishment of an institution destined, as we trust, to exert a beneficial influence on the progress of useful knowledge at home and abroad, and through that on the general cause of civilization.

You will observe that I am careful to say the progress of science "at home and abroad;" for the study of astronomy in this country, like that of many other branches of natural science, has long since, I am happy to add, passed that point where it is content to repeat the observations and verify the results of European research. It has boldly and successfully entered the field of original investigation, discovery, and speculation; and there is not now a single department of the science in which the names of American observers and mathematicians are not cited by our brethren across the water, side by side with the most eminent of their European contemporaries.

This state of things is certainly recent. During the colonial period, and in the first generation after the Revolution, no department of science was, for obvious causes, very extensively cultivated in America, — astronomy perhaps as much as the kindred branches. The improvement in the quadrant commonly known as Hadley's had already been made at Philadelphia by Godfrey in the early part of the last century, and the beautiful invention of the collimating telescope was made at a later period by Rittenhouse, an astronomer of distinguished repute. The transits of Venus of 1761 and 1769 were observed in different parts of the country; orreries, a favorite scientific toy in the last century, were constructed in Philadelphia and Boston; and some respectable scientific essays are contained and valuable observations are recorded in the early volumes of the transactions of the Philosophical Society at Philadelphia and the American Academy of Arts and Sciences at Boston and Cambridge. But in the absence of a numerous class of men of science to encourage and aid each other, in a state of the country as yet too poor to extend a liberal patronage to the expensive arts, without observatories and without valuable instruments, little of importance could be expected in the higher walks of astronomical research.

The greater the credit due for the achievement of an enterprise commenced in the early part of the present century, and which would reflect honor on the science of any country and any age, I mean the translation and commentary on Laplace's

Mécanique Celeste, by Bowditch; a work whose merit I am myself wholly unable to appreciate, but which I have been led to think places the learned translator and commentator on a level with the ablest astronomers and geometers of the day. This work may be considered as opening a new era in the history of American science. The country was still almost wholly deficient in instrumental power; but the want was generally felt by men of science, and the public mind in various parts of the Union began to be turned towards the means of supplying it. In 1825, President John Quincy Adams brought the subject of a National Observatory before congress. Political considerations prevented its being favorably entertained at that time; and it was not till 1842, and as an incident of the exploring expedition, that an appropriation was made for a *depot* for the charts and instruments of the navy. On this modest basis has been reared the National Observatory at Washington; an institution which has already taken and fully sustains an honorable position among the scientific establishments of the age.

Besides the institution at Washington, fifteen or twenty observatories have, within the last few years, been established in different parts of the country, some of them on a modest scale for the gratification of the scientific taste and zeal of individuals, others on a broad foundation of expense and usefulness. In these establishments, public and private, the means are provided for the highest order of astronomical observation, research, and instruction. There is already in the country an amount of instrumental power (to which addition is constantly making), and of mathematical skill on the part of our men of science, adequate to a manly competition with their European contemporaries in astronomy and the branches of science theoretical and applied connected with it. The proceedings of the present meeting of the American Association fully justify this remark. The fruits are already before the world in the triangulation of several of the States, in the great work of the coast survey, in the numerous scientific surveys of the interior of the continent, in the astronomical department of the exploring expedition, in the more recent scientific expedition to Chili; — in the brilliant hydrographical labors of the observatory at Washington; in the published observations of Washington and Cambridge; in the general character of the contents of the journal conducted by the Nestor of American Science, now in its eighth lustrum, of the Sidereal Messenger, and the Astronomical Journal; in the National Ephemeris; in the great chronometrical expeditions to determine the longitude of Cambridge, better ascertained than that of Paris was till within the last year; in the prompt rectification of the errors in the predicted elements of Neptune, in its identification with Lalande's missing star, and in the calculation of its ephemeris; in the discovery of the satellite of Neptune, of the eighth satellite of Saturn, and of the innermost of its rings; in the establishment, both by observation and theory, of the non-solid character of Saturn's rings; in the recent remarkable speculations on the nature of the Zodiacal light; in the separation and measurement of many double and triple stars, amenable only to superior instrumental power; in the immense labor already performed in preparing Star Catalogues, and in numerous accurate observations of standard stars; in the diligent and successful observation of the meteoric showers; in an extensive series of magnetic observations; in the discovery of an asteroid and ten or twelve telescopic comets; in the resolution of nebulæ, which have defied every thing in Europe but Lord Rosse's great Reflector; in the application of electricity to the measurement of differences in longitude, in the corrected ascertainment of the velocity of the electro-magnetic fluid, and its truly wonderful uses in recording astronomical observations. These are but a portion of the achievements of American astronomical science within fifteen or twenty years, and fully justify the most sanguine anticipations of its further progress.

How far our astronomers may be able to pursue their researches, will depend upon the resources of our public institutions, and the liberality of wealthy individuals in furnishing the requisite means. With the exception of the observatories at Washington and West Point, little can be done or expected to be done by the government of the Union or the States; but in this, as in every thing else connected with the patronage of art and science, the great dependence, and may I not add the safe dependence, as it ever has been, must continue to be upon the bounty of enlightened, liberal, and public-spirited individuals.

It is by a signal exercise of this bounty, my friends, that we are called together to-day. The munificence of several citizens of this ancient city, among whom the first place is due to the generous lady, whose name has with great propriety been given to the institution, has furnished the means for the foundation of the Dudley Observatory at Albany. On a commanding elevation, on the northern edge of the city, liberally given for that purpose by the head of a family (Van Rensselaer) in which the patronage of science is hereditary, a building of ample dimensions has been erected, upon a plan which combines all the requisites of solidity, convenience, and taste. A large portion of the expense of the structure has been defrayed by Mrs. Blandina Dudley, to whose generosity, and that of several other public spirited individuals, the institution is also indebted for the provision which has been made for an adequate supply of first-class instruments, executed and to be executed by the most eminent makers in Europe and America; and which, it is confidently expected, will yield to none of their class in any observatory in the world.*

With a liberal supply of instrumental power; established

* For this description of the Dudley Observatory, I am indebted to a valuable article on American Observatories by Professor Loomis in Harper's Magazine for June, 1856, p. 49.

in a community to whose intelligence and generosity its support may be safely confided, and whose educational institutions are rapidly realizing the conception of a university; countenanced by the gentleman who conducts the United States Coast Survey with such scientific skill and administrative energy, and by the men of science generally in the United States; committed to the immediate supervision of an astronomer (Dr. B. A. Gould, Jr.), to whose distinguished talent has been added the advantage of a thorough scientific education in the most renowned universities of Europe, and who, as the editor of the American Astronomical Journal, has shown himself to be fully qualified for the high trust; — under these favorable circumstances, the Dudley Observatory at Albany now takes its place among the scientific foundations of the country and the world.

It is no affected modesty which leads me to express the regret that this interesting occasion could not have taken place under somewhat different auspices. I feel that the duty of addressing this great and enlightened assembly, comprising so much of the intelligence of the community and of the science of the country, ought to have been elsewhere assigned; that it should have devolved upon some one of the eminent persons, many of whom I see around me, to whom you have been listening the past week, who as observers and geometers could have treated the subject with a master's power; astronomers, whose telescopes have penetrated the depths of the heavens, or mathematicians, whose analysis unthreads the maze of their wondrous mechanism. If, instead of commanding, as you easily could have done, qualifications of this kind, your choice has rather fallen on one, making no pretensions to the honorable name of a man of science, — but whose delight it has always been to turn aside from the dusty and thankless paths of active life, for an interval of recreation in the green fields of sacred nature in all her kingdoms, — it is, I presume, because you have desired, on an occasion of this kind, necessarily of a popular character, that those views of the subject should be presented which address themselves to the general intelligence of the community, and not to its select scientific circles. For astronomy perhaps to a greater extent, than any other department of natural science, exhibits phenomena, which, while they task the highest powers of philosophical research, are also well adapted to arrest the attention of minds barely tinctured with scientific culture, and even to touch the sensibilities of the wholly uninstructed observer. The profound investigations of the chemist into the ultimate constitution of material nature, the minute researches of the physiologist into the secrets of animal life, the transcendental logic of the geometer bristling in a notation, the very sight of which terrifies the uninitiated, are lost on the common understanding. But the unspeakable glories of the rising and the setting sun; the serene majesty of the moon, as she walks in full-orbed brightness through the heavens; the soft witchery of the morning and the evening star; the imperial splendors of the firmament on a bright unclouded night; the comet, whose streaming banner floats over half the sky, — these are objects which charm and astonish alike the philosopher and the peasant; — the mathematician who weighs the masses and defines the orbits of the heavenly bodies, and the untutored observer who sees nothing beyond the images painted upon the eye.

An astronomical observatory, in the general acceptation of the word, is a building erected for the reception and appropriate use of astronomical instruments, and the accommodation of the men of science employed in making and reducing observations of the heavenly bodies. These instruments are mainly of three classes, to which I believe all others of a strictly astronomical character may be referred.

1st. The instruments, by which the heavens are inspected, with a view to discover the existence of those celestial bodies which are not visible to the naked eye, (beyond all comparison more numerous than those which are,) and to observe the magnitude, shapes, and other sensible qualities, both of those which are and those which are not thus visible to the unaided sight. The instruments of this class are designated by the general name of Telescope; and are of two kinds;—the refracting telescope, which derives its magnifying power from a system of convex lenses; and the reflecting telescope, which receives the image of the heavenly body upon a concave mirror.

2d. The second class of instruments consists of those, which are designed principally to measure the angular distances of the heavenly bodies from each other, and their time of passing the meridian. The transit instrument, the meridian circle, the mural circle, the heliometer, and the sextant, belong to this class. The brilliant discoveries of astronomy are for the most part made with the first class of instruments;—its practical results wrought out by the second.

3d. The third class contains the clock, with its subsidiary apparatus for measuring the time and marking its subdivisions, with the greatest possible accuracy;—indispensable auxiliary of all the instruments, by which the positions and motions of the heavenly bodies are observed, and measured, and recorded.

The telescope may be likened to a wondrous Cyclopean eye, endued with superhuman power, by which the astronomer extends the reach of his vision to the further heavens, and surveys galaxies and universes compared with which the solar system is but an atom floating in the air. The transit may be compared to a measuring rod which he lays from planet to planet and from star to star, to ascertain and mark off the heavenly spaces, and transfer them to his note-book. The clock is the marvellous apparatus by which he equalizes and divides into nicely measured parts a portion of that unconceived infinity of duration, without beginning and without end, in which all existence floats as on a shoreless and bottomless sea.

In the contrivance and the execution of these instruments, the utmost stretch of inventive skill and mechanical ingenuity has been put forth. To such perfection have they been carried, that a single second of magnitude or space is rendered a distinctly visible and appreciable quantity. "The arc of a circle," says Sir J. Herschell, "subtended by one second, is less than the two hundred thousandth part of the radius, so that on a circle of six feet in diameter, it would occupy no greater linear extent than $\frac{1}{5700}$ part of an inch; a quantity requiring a powerful microscope to be *discerned* at all."* The largest body in our system, the sun, whose real diameter is 882,000 miles subtends, at a distance of 95,000,000 miles, but an angle of a little more than 32′; while so admirably are the best instruments constructed, that both in Europe and America a satellite of Neptune, an object of comparatively inconsiderable diameter, has been discovered at a distance of 2,850 millions of miles.

The object of an Observatory, erected and supplied with instruments of this admirable construction and at proportionate expense, is, as I have already intimated, to provide for an accurate and systematic survey of the heavenly bodies, with a view to a more correct and extensive acquaintance with those already known, and as instrumental power and skill in using it increase, to the discovery of bodies hitherto invisible, and in both classes of objects to the determination of their distances, their times of passing the meridian, their relations to each other, and the laws which govern their movements.

Why should we wish to obtain this knowledge? What inducement is there to expend large sums of money in the erection of Observatories, in furnishing them with costly in-

* Herschell's Outlines of Astronomy, § 131.

struments, and in the support of the men of science employed in making, discussing, and recording, for successive generations, these minute observations of the heavenly bodies?

In an exclusively scientific treatment of this subject, an inquiry into its utilitarian relations would be superfluous, — even wearisome. But on an occasion like the present, you will not, perhaps, think it out of place, if I briefly answer the question what is the use of an astronomical observatory, and what benefit may be expected from the operations of such an establishment in a community like ours?

I. In the first place, then, we derive from the observations of the heavenly bodies which are made at an observatory, our only adequate measures of time and our only means of comparing the time of one place with the time of another. Our artificial timekeepers — clocks, watches, and chronometers — however ingeniously contrived and admirably fabricated, are but a transcript, so to say, of the celestial motions, and would be of no value without the means of regulating them by observation. It is impossible for them under any circumstances to escape the imperfection of all machinery, the work of human hands; — and the moment we remove with our timekeeper east or west, it fails us. It will keep home time alone, like the fond traveller who leaves his heart behind him. The artificial instrument is of incalculable utility, but must itself be regulated by the eternal clock-work of the skies.

This single consideration is sufficient to show how completely the daily business of life is affected and controlled by the heavenly bodies. It is they and not our main-springs, our expansion balances, and our compensation pendulums, which give us our time. To reverse the line of Pope, —

> 'T is with our watches as our judgments; none
> Go just alike, but each believes his own; —

But for all the kindreds and tribes and tongues of men, —

each upon their own meridian,—from the Arctic pole to the equator, from the equator to the Antarctic pole, the eternal sun strikes twelve at noon, and the glorious constellations, far up in the everlasting belfries of the skies, chime twelve at midnight;—twelve for the pale student over his flickering lamp, twelve amid the flaming wonders of Orion's belt, if he crosses the meridian at that fated hour;—twelve by the weary couch of languishing humanity, twelve in the star-paved courts of the Empyrean;—twelve for the heaving tides of the ocean; twelve for the weary arm of labor; twelve for the toiling brain; twelve for the watching, waking, broken heart; twelve for the meteor which blazes for a moment and expires; twelve for the comet whose period is measured by centuries; twelve for every substantial, for every imaginary thing, which exists in the sense, the intellect, or the fancy, and which the speech or thought of man, at the given meridian, refers to the lapse of time.

Not only do we resort to the observation of the heavenly bodies for the means of regulating and rectifying our clocks, but the great divisions of day and month and year are derived from the same source. By the constitution of our nature the elements of our existence are closely connected with the celestial times. Partly by his physical organization, partly by the habit,—second nature,—of the race from the dawn of creation, man as he is and the times and seasons of the heavenly bodies are part and parcel of one system. The first great division of time, the *day-night* (nychthemerum), for which we have no precise synonym in our language, with its primal alternation of waking and sleeping, of labor and rest, is a vital condition of the existence of such a creature as man. The revolution of the *year*, with its various incidents of summer and winter and seed-time and harvest, is not less involved in all our social material and moral progress. It is true that at the poles and on the equator, the effects of these revolutions are variously modified or wholly disappear, but as the necessary consequence, human life is extinguished at the poles, and on the equator attains only a languid or feverish development.* Those latitudes only, in which the great motions and cardinal positions of the earth exert a mean influence, exhibit man in the harmonious expansion of his powers. The lunar period, which lies at the foundation of the *month*, is less vitally connected with human existence and development; but is proved by the experience of every age and race to be eminently conducive to the progress of civilization and culture.

But indispensable as are these heavenly measures of time to our life and progress, and obvious as are the phenomena on which they rest, yet, owing to the circumstance that, in the economy of nature, the day, the month, and the year are not exactly commensurable, some of the most difficult questions in practical astronomy are those, by which an accurate division of time, applicable to the various uses of man, is derived from the observation of the heavenly bodies. I have no doubt that, to the Supreme Intelligence which created and rules the universe, there is a harmony hidden to us in the numerical relation to each other of days, months, and years; but in our ignorance of that harmony, their practical adjustment to each other is a work of difficulty. The great embarrassment which attended the reformation of the calendar, after the error of the Julian period had, in the lapse of centuries, reached ten (or rather twelve) days, sufficiently illustrates this remark. It is most true that scientific difficulties did not form the chief obstacle. Having been proposed under the auspices of the Roman Pontiff, the protestant world, for a century and more, rejected the new style. It was in various places the subject of controversy, collision, and bloodshed.† It was not adopted in England till nearly two cen-

* Guyot, Earth and Man, p. 231 et seq.

† Stern's Himmelskunde, p. 72.

turies after its introduction at Rome; and in the country of the Struves and the Pulkova equatorial, they persist at the present day, for civil purposes, in adding eleven minutes and twelve seconds to the length of the tropical year.

II. The second great practical use of an Astronomical Observatory is connected with the science of Geography. The first page of the history of our continent illustrates this connection. Profound meditation on the sphericity of the earth was one of the main reasons which led Columbus to undertake his momentous voyage, and his thorough acquaintance with the astronomical science of that day was, in his own judgment, what enabled him to overcome the almost innumerable obstacles which attended its prosecution.* In return, I find that Copernicus, in the very commencement of his immortal work,† appeals to the discovery of America as completing the demonstration of the sphericity of the earth. Much of our knowledge of the figure, size, density, and position of the earth as a member of the solar system is derived from this science, and it furnishes us the means of performing the most important operations of practical geography. Latitude and longitude, which lie at the basis of all descriptive geography, are determined by observation. No map deserves the name, on which the position of important points has not been astronomically determined. Some even of our most important political and administrative arrangements depend upon the coöperation of this science. Among these I may mention the land-system of the United States, and the determination of the boundaries of the country.

I believe that till it was done by the Federal Government, a uniform system of mathematical survey had never in any country been applied to an extensive territory. Large grants and sales of public land took place before the Revolution and

* Humboldt, Histoire de la géographie, etc. Tom. I. p. 17.

† Copernicus de Revolutionibus orbium cœlestium, Fol. 2.

in the interval between the peace and the adoption of the Constitution; but the limits of these grants and sales were ascertained by sensible objects, by trees, streams, rocks, hills, and by reference to adjacent portions of territory, previously surveyed. The uncertainty of boundaries thus defined was a never-failing source of litigation. Large tracts of land in the Western country granted by Virginia, under this old system of special and local survey, were covered with conflicting claims, and the controversies to which they gave rise formed no small part of the business of the Federal Court after its organization. But the adoption of the present land-system brought order out of chaos. The entire public domain is now scientifically surveyed before it is offered for sale; it is laid off into ranges, townships, sections, and smaller divisions with unerring accuracy, resting on the foundation of base and meridian lines; — and I have been informed that under this system, scarce a case of contested location and boundary has ever presented itself in court. The general land-office contains maps and plans, in which every quarter-section of the public land is laid down with mathematical precision. The superficies of half a continent is thus transferred in miniature to the bureaus at Washington; — while the local land-offices contain transcripts of these plans, copies of which are furnished to the individual purchaser. When we consider the tide of population annually flowing into the public domain, and the immense importance of its efficient and economical administration, the utility of this application of astronomy will be duly estimated.*

I will here venture to repeat an anecdote which I heard lately from a son of the late Hon. Timothy Pickering. Mr. Octavius Pickering, on behalf of his father, had applied to Mr. David Putnam of Marietta, to act as his legal adviser,

* See an article on the Public Lands by the author of this Address, American Almanac for 1832, p. 145.

with respect to certain land claims in the Virginia military district, in the State of Ohio. Mr. Putnam declined the agency. He had had much to do with business of that kind and found it beset with endless litigation. "I have never," he adds, "succeeded but in a single case, and that was a location and survey made by General Washington before the Revolution, and I am not acquainted with any surveys, except those made by him, but what have been litigated."

At this moment, a most important survey of the coast of the United States is in progress; an operation of the utmost consequence, in reference to the geography, commerce, navigation, and hydrography of the country. The entire work, I need scarce say, is one of practical astronomy. The scientific establishment which we this day inaugurate is looked to for important coöperation in this great undertaking; — and will no doubt contribute efficiently to its prosecution.

Astronomical observation furnishes by far the best means of defining the boundaries of States, when the lines are of great length and run through unsettled countries. Natural indications like rivers and mountains, however distinct in appearances, are in practice subject to unavoidable error. By the treaty of 1783, a boundary was established between the United States and Great Britain, depending partly on the course of rivers, and upon the highlands dividing the waters which flow into the Atlantic Ocean from those which flow into the St. Lawrence. It took twenty years to find out which river was the true St. Croix, that being the starting point. England then having made the extraordinary discovery that the Bay of Fundy is not a part of the Atlantic Ocean, forty years more were passed in the unsuccessful attempt to re-create the Highlands which this strange doctrine had annihilated; and just as the two countries were on the verge of a war, the controversy was settled by compromise. Had the boundary been accurately described by lines of latitude and longitude, no dispute could have arisen. No dispute arose as to the boundary between the United States and Spain, and her successor, Mexico, where it runs through untrodden deserts, and over pathless mountains, along the forty-second degree of latitude. The identity of rivers may be disputed as in the case of the St. Croix; the course of mountain chains is too broad for a dividing line; the division of streams, as experience has shown, is uncertain, but a degree of latitude is written on the heavenly sphere; and nothing but an observation is required to read the record.

But scientific elements, like sharp instruments, must be handled with care. A part of our boundary between the British Provinces ran upon the forty-fifth degree of latitude; and about forty years ago, an expensive fortress was commenced by the government of the United States at Rouse's Point, on Lake Champlain, on a spot intended to be just within our limits. When the line came to be more carefully surveyed the fortress turned out to be on the wrong side; we had been building an expensive fortification for our neighbor. But in the general compromises of the Treaty of Washington by the Webster and Ashburton Treaty of the 9th of August, 1842, the fortress was left within our limits.*

Errors still more serious had nearly resulted a few years since in a war with Mexico. By the treaty of Guadalupe Hidalgo, of the 2d of February, 1848, the boundary line between the United States and that country was in part described by reference to the town of El Paso, as laid down on a specified map of the United States, of which a copy was appended to the treaty. This boundary was to be surveyed and run by a joint commission of men of science. It soon appeared that errors of two or three degrees existed in the projection of the map. Its lines of latitude and longitude did not conform to the topography of the region; so that it was impossible to execute the text of the treaty. The famous Mesilla Valley

* Webster's Works, Vol. I. pp. 110, 115.

was a part of the debatable ground, and the sum of ten millions of dollars paid to the Mexican government, for that and for an additional strip of territory on the south-west, was the smart-money, which expiated the inaccuracy of the map; the necessary result perhaps of the want of good materials for its construction. Ten millions of dollars would have gone a good way toward the expense of a National Observatory and of a map of the continent, constructed with entire accuracy.

It became my official duty, in London, a few years ago, to apply to the British government for an authentic statement of their claim to jurisdiction over New Zealand. The official Gazette for the 2d of October, 1840, was sent me from the Foreign office, as affording the desired information. This number of the Gazette contained the proclamations issued by the lieutenant-governor of New Zealand "in pursuance of the instructions he received from the Marquess of Normanby, one of Her Majesty's principal Secretaries of State," asserting the jurisdiction of his government over the islands of New Zealand, and declaring them to extend "from thirty-four degrees thirty minutes north, to forty-seven degrees ten minutes south latitude." It is scarcely necessary to say, that south latitude was intended in both instances. This error of sixty-nine degrees of latitude, which would have extended the claim of British jurisdiction over the whole breadth of the Pacific, had apparently escaped the notice of that government.

It would be easy to multiply illustrations of the great practical importance of accurate scientific designations drawn from astronomical observation, in various relations connected with boundaries, surveys, and other geographical purposes; but I must hasten to

III. A third important department, in which the services rendered by astronomy are equally conspicuous. I refer to commerce and navigation. It is chiefly owing to the results of astronomical observation, that modern commerce has attained such a vast expansion, compared with that of the ancient world. I have already reminded you that accurate astronomical notions contributed materially to the conception in the mind of Columbus of his immortal enterprise, and to the practical success with which it was conducted. It was mainly his skill in the use of astronomical instruments, imperfect as they were, which enabled him, in spite of the bewildering variations of the compass, to find his way across the ocean.

With the progress of the true system of the universe towards general adoption, the problem of finding the longitude at sea presented itself. This was the avowed object of the foundation of the Observatory at Greenwich,* and no one subject has received more of the attention of astronomers than those investigations of the lunar theory, on which the requisite tables of the navigator are founded. The pathways of the ocean are marked out in the sky above. The eternal lights of the heavens are the only Pharos whose beams never fail; which no tempest can shake from its foundation. Within my recollection, it was deemed a necessary qualification for the master and the mate of a merchant-ship, and even for a prime hand, to be able to "work a lunar," as it was called.† The improvements in the chronometer have in prac-

* Grant's History of Physical Astronomy, p. 460.

† The following amusing anecdote is found in Baron Zach's *Correspondence Astronomique,* Vol. IV. p. 62. It is a part of the Baron's account of his visit to *Cleopatra's Barge,* which entered the harbor of Genoa in 1817. The Baron was told by the proprietor and commander of the vessel, that his black cook could find the ship's longitude by observation. "'There he is,' said the young man, pointing to a negro at the stern of the vessel, in his white apron, with a fowl in one hand, and a dressing-knife in the other. 'Come here, John, cried the captain, this gentleman is surprised at your calculating the longitude; tell him about it. *Zach.* What method do you employ in calculating the longitude by lunar distances? *The Cook.* It is indifferent to me. I make use of the method of Maskelyne, Lyons, of Witchell, and of Bowditch; but I prefer Dunthorne, with which I am more familiar and which is shorter.' I could not express my surprise at language like this from a black cook, with a bleeding fowl in one hand, and a larding-knife in the other."

Dr. Bowditch in early life was supercargo of a vessel trading to the East. His tice, to a great extent, superseded this laborious operation, but Observation remains, and unquestionably will for ever remain, the only dependence for ascertaining the ship's time and deducing the longitude from the comparison of that time with the chronometer.

It may perhaps be thought that astronomical science is brought already to such a state of perfection, that nothing more is to be desired, or at least that nothing more is attainable in reference to such practical applications as I have described. This, however, is an idea which generous minds will reject, in this as in every other department of human knowledge. In astronomy, as in every thing else, the discoveries already made, theoretical or practical, instead of exhausting the science, or putting a limit to its advancement, do but furnish the means and instruments of further progress. I have no doubt we live on the verge of discoveries and inventions in every department, as brilliant as any that have ever been made; that there are new truths, new facts ready to start into recognition on every side; and it seems to me there never was an age since the dawn of time, when men ought to be less disposed to rest satisfied with the progress already made, than the age in which we live; for there never was an age more distinguished for ingenious research, for novel result, and bold generalization.

That no further improvement is desirable in the means and methods of ascertaining the ship's place at sea, no one I think will from experience be disposed to assert. The last

captain, being asked, on one occasion, at Manilla, how he had contrived to find his way, in the face of a north-east monsoon, by mere dead reckoning, replied, "that he had a crew of twelve men, every one of whom could take and work a lunar observation as well, for all practical purposes, as Sir Isaac Newton himself, were he alive." During this conversation, Dr. Bowditch sat, "as modest as a maid, saying not a word, but holding his slate pencil in his mouth," while another person remarked that, "there was more knowledge of navigation on board that ship, than there was in all the vessels that have floated in Manilla bay." — Memoir of Dr. Bowditch, by Nathaniel Ingersoll Bowditch, p. 29.

time I crossed the Atlantic I walked the quarter-deck with the officer in charge of the noble vessel, on one occasion, when we were driving along before a leading breeze and under a head of steam, beneath a starless sky at midnight, at the rate certainly of ten or eleven miles an hour. There is something sublime, but approaching the terrible, in such a scene; — the rayless gloom, the midnight chill, the awful swell of the deep, the dismal moan of the wind through the rigging, the all but volcanic fires within the hold of the ship; — I scarce know an occasion in ordinary life in which a reflecting mind feels more keenly its hopeless dependence on irrational forces beyond its own control. I asked my companion how nearly he could determine his ship's place at sea under favorable circumstances. Theoretically, he answered, I think, within a mile; practically and usually within three or four. My next question was, How near do you think we may be to Cape Race? — that dangerous headland which pushes its iron-bound unlighted bastions from the shore of Newfoundland far into the Atlantic, — first land-fall to the homeward-bound American vessel.* We must, said he, by our last observations and reckoning, be within three or four miles of Cape Race. A comparison of these two remarks, under the circumstances in which we were placed at the moment, brought my mind to the conclusion, that it is greatly to be wished that the means should be discovered of finding the ship's place more accurately, or that navigators would give Cape Race a little wider berth. Still I do not remember that one of the steam-packets between England and America was ever lost upon that formidable point.

It appears to me by no means unlikely that, with the improvement of instrumental power, and of the means of ascertaining the ship's time with exactness, as great an advance

* Since the voyage in question was made (in 1845), a light-house has been built on Cape Race.

beyond the present state of art and science in finding a ship's place at sea may take place, as was effected by the invention of the reflecting quadrant, the calculation of lunar tables, and the improved construction of chronometers.

In the wonderful versatility of the human mind, the improvement, when it takes place, will very probably be made by paths where it is least expected. The great inducement of Mr. Babbage to attempt the construction of an engine, by which astronomical tables could be calculated, and even printed, by mechanical means and with entire accuracy, was the errors in the requisite tables. Nineteen such errors, in point of fact, were discovered in an edition of Taylor's logarithms printed in 1796; some of which might have led to the most dangerous results in calculating a ship's place. These nineteen errors (of which one only was an error of the press) were pointed out in the Nautical Almanac for 1832. In one of these *errata* the seat of the error was stated to be in cosine of 14° 18′ 3″. Subsequent examination showed that there was an error of one second in this correction, and accordingly in the Nautical Almanac of the next year a new correction was necessary. But in making the new correction of one second, a new error was committed of ten degrees. Instead of cosine 14° 18′ 2″, the correction was printed cosine 4° 18′ 2″, making it still necessary, in some future edition of the Nautical Almanac, to insert an *erratum* in an *erratum* of the *errata* in Taylor's logarithms.*

In the hope of obviating the possibility of such errors, Mr. Babbage projected his calculating, or, as he prefers to call it, his difference machine. Although this extraordinary undertaking has been arrested in consequence of the enormous expense attending its execution, enough has been achieved to show the mechanical possibility of constructing an engine of this kind, and even one of far higher powers, of which Mr.

* Edinburgh Review, Vol. LIX. p. 282.

Babbage has matured the conception, devised the notation, and executed in part the drawings, — themselves an imperishable monument of the genius of the author.

I happened on one occasion to be in company with this highly distinguished man of science, whose social qualities are as pleasing as his constructive talent is marvellous, when another eminent *savant*, Count Strzelecki, just returned from his Oriental and Australian tour, observed that he found among the Chinese a great desire to know something more of Mr. Babbage's calculating machine, and especially whether like their own *swanpan* it could be made to go into the pocket. Mr. Babbage good-humoredly observed that thus far he had been very much out of pocket with it.

Whatever advances may be made in astronomical science, theoretical or applied, I am strongly inclined to think that they will be made in connection with an increased command of instrumental power. The natural order in which the human mind proceeds in the acquisition of astronomical knowledge, is minute and accurate observation of the phenomena of the heavens, the skilful discussion and analysis of these observations, and sound philosophy in generalizing the results.

In pursuing this course, however, a difficulty presented itself, which for ages proved insuperable, and which to the same extent has existed in no other science, namely, that all the leading phenomena are in their appearance delusive. It is indeed true that in all sciences, superficial observation can only lead, except by chance, to superficial knowledge; but I know of no branch in which, to the same degree as in astronomy, the great leading phenomena are the reverse of true, while they yet appeal so strongly to the senses, that sagacious philosophers in antiquity who could foretell eclipses, and who discovered the precession of the equinoxes, still believed that the earth was at rest in the centre of the universe, and that all the hosts of heaven performed a daily revolution about it as a centre.

It usually happens in scientific progress, that when a great fact is at length discovered, it approves itself at once to all competent judges. It furnishes a solution to so many problems and harmonizes with so many other facts, that all the other *data*, as it were, crystallize at once about it. In modern times we have often witnessed such an impatience, so to say, of great truths to be discovered, that it has frequently happened that they have been found out simultaneously by more than one individual. A disputed question of priority is an event of very common occurrence. Not so with the true theory of the heavens. So complete is the deception practised on the senses, that it failed more than once to yield to the announcement of the truth; and it was only when the visual organs were armed with an almost preternatural instrumental power, that the great fact found admission to the human mind.

It is supposed that in the very infancy of science, Pythagoras or his disciples explained the apparent motion of the heavenly bodies about the earth, by the diurnal revolution of the earth on its axis. But this theory, though bearing so deeply impressed upon it the great seal of truth, *simplicity*, was in such glaring contrast with the evidence of the senses, that it failed of acceptance in antiquity or the middle ages. It found no favor with minds like those of Aristotle, Archimedes, Hipparchus, Ptolemy, or any of the acute and learned Arabian or mediæval astronomers. All their ingenuity and all their mathematical skill were exhausted in the development of a wonderfully complicated and ingenious but erroneous theory. The great master truth, rejected for its simplicity, lay, disregarded, at their feet.

At the second dawn of science, the great fact again beamed into the mind of Copernicus. Now, at least, in that glorious age which witnessed the invention of printing, the great mechanical engine of intellectual progress, and the discovery of America, we may expect that this long-hidden revelation, a second time proclaimed, will command the assent of mankind. But the sensible phenomena were still too strong for the theory;—the glorious delusion of the rising and the setting sun could not be overcome. Tycho de Brahe furnished his observatory with instruments superior in number and quality to all that had been collected before; but the great instrument of discovery, which, by augmenting the optic power of the eye, enables it to penetrate beyond the apparent phenomena and to discern the true constitution of the heavenly bodies, was wanting at Uranienburg. The observations of Tycho, as discussed by Keppler, conducted that most fervid, powerful, and sagacious mind to the discovery of some of the most important laws of the celestial motions; but it was not till Galileo, at Florence, had pointed his telescope to the sky, that the Copernican system could be said to be firmly established in the scientific world.*

On this great name, my friends, assembled as we are to dedicate a temple to instrumental Astronomy, we may well pause for a moment.

There is much, in every way, in the city of Florence to excite the curiosity, to kindle the imagination, and to gratify the taste. Sheltered on the north by the vine-clad hills of Fiesolé, whose Cyclopean walls carry back the antiquary to ages before the Roman, before the Etruscan power, the flowery city (Fiorenza) covers the sunny banks of the Arno with its stately palaces. Dark and frowning piles of mediæval structure, a majestic dome the prototype of St. Peter's, basilicas which enshrine the ashes of some of the mightiest of the dead, the stone where Dante stood to gaze on the *cam-*

* It is another interesting coincidence of events in the year 1609, that Keppler's works *de Motu Martis* and *Astronomia Nova,* in which his two first laws are propounded, appeared in this year. I am indebted for this suggestion to Dr. B. A. Gould, Jun.

panile, the house of Michael Angelo still occupied by a descendant of his lineage and name,—his hammer, his chisel, his dividers, his manuscript poems, all as if he had left them but yesterday;—airy bridges which seem not so much to rest on the earth as to hover over the waters they span;—the loveliest creations of ancient art, rescued from the grave of ages again to "enchant the world;"—the breathing marbles of Michael Angelo, the glowing canvas of Raphael and Titian;—museums filled with medals and coins of every age from Cyrus the younger, and gems and amulets and vases from the sepulchres of Egyptian Pharoahs coeval with Joseph, and Etruscan Lucumons that swayed Italy before the Romans;—libraries stored with the choicest texts of ancient literature;—gardens of rose and orange and pomegranate and myrtle;—the very air you breathe languid with music and perfume,—such is Florence. But among all its fascinations addressed to the sense, the memory, and the heart, there was none to which I more frequently gave a meditative hour during a year's residence, than to the spot where Galileo Galilei sleeps beneath the marble floor of Santa Croce; no building on which I gazed with greater reverence, than I did upon the modest mansion at Arcetri, villa at once and prison, in which that venerable sage, by command of the Inquisition, passed the sad closing years of his life;—the beloved daughter on whom he had depended to smoothe his passage to the grave laid there before him; the eyes with which he had discovered worlds before unknown, quenched in blindness:—

> Ahimè! quegli occhi si son fatti oscuri,
> Che vider più di tutti i tempi antichi,
> E luce fur dei secoli futuri.

That was the house "where," says Milton, (another of those of whom the world was not worthy,) "I found and visited the famous Galileo, grown old,—a prisoner to the

Inquisition, for thinking on astronomy, otherwise than as the Dominican and Franciscan licensers thought."* Great heavens! what a tribunal, what a culprit, what a crime! Let us thank God, my friends, that we live in the nineteenth century. Of all the wonders of ancient and modern art, statues and paintings, and jewels and manuscripts, the admiration and the delight of ages, — there was nothing which I beheld with more affectionate awe, than that poor rough tube, a few feet in length, the work of his own hands, that very "optic glass" through which the "Tuscan Artist" viewed the moon,

> "At evening from the top of Fesolé
> Or in Valdarno, to descry new lands,
> Rivers, or mountains, in her spotty globe:"

that poor little spy-glass (for it is scarcely more) through which the human eye first distinctly beheld the surface of the moon, — first discovered the phases of Venus, the satellites of Jupiter, and the seeming handles of Saturn, — first penetrated the dusky depths of the heavens, — first pierced the clouds of visual error, which from the creation of the world involved the system of the Universe.

There are occasions in life in which a great mind lives years of rapt enjoyment in a moment. I can fancy the emotions of Galileo, when, first raising the newly constructed telescope to the heavens, he saw fulfilled the grand prophecy of Copernicus, and beheld the planet Venus crescent like the moon. It was such another moment as that when the immortal printers of Mentz and Strasburg received the first copy of the Bible into their hands, the work of their divine Art; — like that when Columbus, through the gray dawn of the 12th October, 1492, (Copernicus, at the age of eighteen, was then

* Milton's Prose Works, Vol. I. p. 313.

a student at Cracow,)* beheld the shores of San Salvador;— like that when the law of gravitation first revealed itself to the intellect of Newton;—like that when Franklin saw by the stiffening fibres of the hempen cord of his kite, that he held the lightning in his grasp;—like that when Leverrier received back from Berlin the tidings that the predicted planet was found.

Yes, noble Galileo, thou art right, *E pur si muove.* "It does move." Bigots may make thee recant it; but it moves nevertheless. Yes, the earth moves, and the planets move, and the mighty waters move, and the great sweeping tides of air move, and the empires of men move,—and the world of thought moves, ever onward and upward to higher facts and bolder theories. The Inquisition may seal thy lips, but they can no more stop the progress of the great truth propounded by Copernicus and demonstrated by thee, than they can stop the revolving earth.

Close now, venerable sage, that sightless, tearful eye; it has seen what man never before saw;—it has seen enough. Hang up that poor little spy-glass; it has done its work. Not Herschell nor Rosse has comparatively done more. Franciscans and Dominicans deride thy discoveries now, but the time will come when from two hundred observatories in Europe and America the glorious artillery of science shall nightly assault the skies, but they shall gain no conquests in those glittering fields before which thine shall be forgotten. Rest in peace, great Columbus of the heavens, like him scorned, persecuted, broken-hearted; in other ages, in distant hemispheres, when the votaries of science, with solemn acts of consecration, shall dedicate their stately edifices to the cause of knowledge and truth, thy name shall be mentioned with honor!

It is not my intention, in dwelling with such emphasis

* Kopernik et ses Travaux, par Jean Czynski, p. 29.

upon the invention of the telescope, to ascribe undue importance, in promoting the advancement of science, to the increase of instrumental power. Too much, indeed, cannot be said of the service rendered by its first application in confirming and bringing into general repute the Copernican system; but for a considerable time, little more was effected by the wondrous instrument, than the gratification of curiosity and taste by the inspection of the planetary phases, and the addition of the rings and satellites of Saturn to the solar family. Newton, prematurely despairing of any further improvement in the refracting telescope, applied the principle of reflection, and the nicer observations now made, no doubt hastened the maturity of his great discovery of the law of gravitation; but that discovery was the work of his transcendent genius and consummate skill.

With Bradley in 1741, a new period commenced in instrumental astronomy, not so much of discovery as of measurement.* The superior accuracy and minuteness, with which the motions and distances of the heavenly bodies were now observed, resulted in the accumulation of a mass of new materials both for tabular comparison and theoretical speculation. These materials formed the enlarged basis of astronomical science between Newton and Sir William Herschell. His gigantic reflectors introduced the astronomer to regions of space before unvisited, extended beyond all previous conception the range of the observed phenomena, and with it proportionably enlarged the range of constructive theory. The discovery of a new primary planet and its attendant satellites was but the first step of his progress into the labyrinth of the heavens. Contemporaneously with his ob-

* Dr. Bowditch in his admirable article in the North American Review, Vol. XX. p. 310. The value of Bradley's observations may be estimated from the labor bestowed upon their reduction by Bessel as late as 1818, in his "fundamenta astronomiæ pro anno MDCCLV, deducta ex observationibus *viri incomparabilis* James Bradley."

servations, the French astronomers and especially La Place, with a geometrical skill scarcely if at all inferior to that of its great author, resumed the whole system of Newton, and brought every phenomenon observed since his time within its laws. Difficulties of fact with which he struggled in vain, gave way to more accurate observations, and problems that defied the power of his analysis yielded to the modern improvements of the calculus.

But there is no *ultima Thule* in the progress of science. With the recent augmentations of telescopic power, the details of the nebular theory proposed by Sir W. Herschell with such courage and ingenuity have been drawn in question. Many — most — of those milky patches in which he beheld what he regarded as cosmical matter, as yet in an unformed state, — the rudimental material of worlds not yet condensed, — have been resolved into stars, as bright and distinct as any in the firmament. I well recall the glow of satisfaction, with which on the 22d of September, 1847, being then connected with the University at Cambridge, I received a letter from the venerable director of the observatory there, beginning with these memorable words: "You will rejoice with me that the great nebula in Orion has yielded to the powers of our incomparable telescope! . . . It should be borne in mind, that this nebula, and that of Andromeda [which has been also resolved at Cambridge] are the last strongholds of the nebular theory.*"

But if some of the adventurous speculations built by Sir William Herschell on the bewildering revelations of his telescope have been since questioned, the vast progress which has been made in sidereal astronomy, (to which, as I understand, the Dudley Observatory will be particularly devoted,) the discovery of the parallax of the fixed stars, the investigation of the interior relations of binary and triple systems of stars, the

* Annals of the Observatory of Harvard College, p. CXXI.

theories for the explanation of the extraordinary, not to say fantastic, shapes discerned in some of the nebulous systems, — whirls and spirals radiating through spaces as vast as the orbit of Neptune,* — the glimpses at systems beyond that to which our sun belongs, — these are all splendid results, which may fairly be attributed to the school of Herschell, and will for ever insure no secondary place to that name in the annals of science.†

In the remarks which I have hitherto made, I have had mainly in view the direct connection of astronomical science with the uses of life and the service of man. But a generous philosophy contemplates the subject in higher relations. It is a remark as old at least as Plato, and is repeated from him more than once by Cicero, that all the liberal arts have a common bond and relationship.‡ The different sciences contemplate as their immediate object the different departments of animate and inanimate nature; but this great system itself is but one. Its various parts are so interwoven with each other, that the most extraordinary relations and unexpected analogies are constantly presenting themselves; and arts and sciences seemingly the least connected, render to each other the most effective assistance.

The history of electricity, galvanism, and magnetism, furnishes the most striking illustration of this remark. Commencing with the meteorological phenomena of our own atmosphere, and terminating with the observation of the remotest heavens, it may well be adduced on an occasion like the present. Franklin demonstrated the identity of lightning and the electric fluid. This discovery gave a great impulse

* See the remarkable memoir of Professor Alexander, "on the origin of the forms and the present condition of some of the clusters of stars, and several of the Nebulæ." — Gould's Astronomical Journal, Vol. III. p. 95.

† For an analysis of the progressive Views of Sir W. Herschell on the Sidereal system, see *Etudes d' Astronomie Stellaire,* par F. G. W. Struve, pp. 23–44.

‡ Archias, § 1; de Oratore, Lib. III. § 21.

to electrical research, with little else in view but the means of protection from the thundercloud. A purely accidental circumstance led the physician Galvani at Bologna to trace the mysterious element, under conditions entirely novel both of development and application. In this new form, it became, in the hands of Davy, the instrument of the most extraordinary chemical operations; and earths and alkalis, touched by the creative wire, started up into metals that float on water, and kindle in the air. At a later period, the closest affinities are observed between electricity and magnetism, on the one hand; while on the other, the relations of polarity are detected between acids and alkalis.—Plating and gilding henceforth become electrical processes. In the last applications of the same subtle medium, it has become the messenger of intelligence across the land and beneath the sea; and is now employed by the astronomer to ascertain the difference of longitudes, to transfer the beats of the clock from one station to another, and to record the moment of his observations with automatic accuracy. How large a share has been borne by America in these magnificent discoveries and applications, among the most brilliant achievements of modern science, will sufficiently appear from the repetition of the names of Franklin, Henry, Morse, Walker, Mitchell, Lock, and Bond.

It has sometimes happened, whether from the harmonious relations to each other of the different departments of science, or from rare felicity of individual genius, that the most extraordinary intellectual versatility has been manifested by the same person. Although Newton's transcendent talent did not blaze out in childhood, yet as a boy he discovered great aptitude for mechanical contrivance. His water-clock, self-moving vehicle, and mill, were the wonder of the village; the latter propelled by a living mouse. Sir David Brewster represents the accounts as differing, whether the mouse was made to advance "by a string attached to its tail," or by "its unavailing attempts to reach a portion of corn placed above the wheel." It seems more reasonable to conclude that the youthful discoverer of the law of gravitation intended, by the combination of these opposite attractions, to produce a balanced movement. It is consoling to the average mediocrity of the race to perceive in these sportive essays, that the mind of Newton passed through the stage of boyhood. But emerging from boyhood, what a bound it made as from earth to heaven! Soon after commencing Bachelor of arts, at the age of twenty-four, he untwisted the golden and silver threads of the solar spectrum; simultaneously, or soon after, conceived the method of fluxions; and arrived at the elemental idea of universal gravity, before he had passed to his Master's degree.* Master of arts, indeed! That degree, if no other, was well bestowed. Universities are unjustly accused of fixing science in stereotype. That diploma is enough of itself to redeem the honors of academical parchment from centuries of learned dulness and scholastic dogmatism.

But the great object of all knowledge is to enlarge and purify the soul, to fill the mind with noble contemplations, and to furnish a refined pleasure. Considering this as the ultimate end of science, no branch of it can surely claim precedence of astronomy. No other science furnishes such a palpable embodiment of the abstractions which lie at the foundation of our intellectual system; the great ideas of time, and space, and extension, and magnitude, and number, and motion, and power. How grand the conception of the ages on ages required for several of the secular equations of the solar system; of distances from which the light of a fixed star would not reach us in twenty millions of years;† of magnitudes compared with which the earth is but a football; of starry hosts, suns like our own, numberless as the sands on the shore; of worlds and systems shooting through the

* Sir David Brewster's Life of Newton, chapter III.

† Nichol's Architecture of the Heavens, p. 160.

infinite spaces, with a velocity compared with which the cannon-ball is a way-worn, heavy-paced traveller!

Much, however, as we are indebted to our observatories for elevating our conceptions of the heavenly bodies, they present even to the unaided sight scenes of glory which words are too feeble to describe. I had occasion, a few weeks since, to take the early train from Providence to Boston; and for this purpose rose at two o'clock in the morning. Every thing around was wrapt in darkness and hushed in silence, broken only by what seemed at that hour the unearthly clank and rush of the train. It was a mild, serene, midsummer's night, — the sky was without a cloud, — the winds were whist. The moon, then in the last quarter, had just risen, and the stars shone with a spectral lustre but little affected by her presence. Jupiter, two hours high, was the herald of the day; the Pleiades just above the horizon shed their sweet influence in the east; Lyra sparkled near the zenith; Andromeda veiled her newly-discovered glories from the naked eye in the south; the steady pointers far beneath the pole looked meekly up from the depths of the north to their sovereign.

Such was the glorious spectacle as I entered the train. As we proceeded, the timid approach of twilight became more perceptible; the intense blue of the sky began to soften; the smaller stars, like little children, went first to rest; the sister-beams of the Pleiades soon melted together; but the bright constellations of the west and north remained unchanged. Steadily the wondrous transfiguration went on. Hands of angels hidden from mortal eyes shifted the scenery of the heavens; the glories of night dissolved into the glories of the dawn. The blue sky now turned more softly gray; the great watch-stars shut up their holy eyes; the east began to kindle. Faint streaks of purple soon blushed along the sky; the whole celestial concave was filled with the inflowing tides of the morning light, which came pouring down from above in one great ocean of radiance; till at length, as we reached the

Blue Hills, a flash of purple fire blazed out from above the horizon, and turned the dewy tear-drops of flower and leaf into rubies and diamonds. In a few seconds, the everlasting gates of the morning were thrown wide open, and the lord of day, arrayed in glories too severe for the gaze of man, began his state.

I do not wonder at the superstition of the ancient Magians, who in the morning of the world went up to the hill-tops of Central Asia, and ignorant of the true God, adored the most glorious work of his hand. But I am filled with amazement, when I am told that in this enlightened age, and in the heart of the Christian world, there are persons who can witness this daily manifestation of the power and wisdom of the Creator, and yet say in their hearts, "there is no God."

Numerous as are the heavenly bodies visible to the naked eye, and glorious as are their manifestations, it is probable that in our own system there are great numbers as yet undiscovered. Just two hundred years ago this year, Huyghens announced the discovery of one satellite of Saturn, and expressed the opinion that the six planets and six satellites then known, and making up the perfect number of *twelve*, composed the whole of our planetary system.* In 1729, an astronomical writer came to the conclusion that there might be other bodies in our system, but that the limit of telescopic power had been reached, and no further discoveries were likely to be made.† The orbit of one comet only had been definitively calculated. Since that time the power of the telescope has been indefinitely increased;—two primary planets of the first class, ten satellites,‡ and forty-three small planets revolving between Mars and Jupiter have been dis-

* Memoirs of the American Academy of Arts and Sciences, New Series, Vol. III. p. 282.

† Admiral Smyth's Celestial Cycle, Vol. I. p. 198.

‡ This computation of the number of satellites discovered since 1729 assumes six as the number of those of Uranus. See J. R. Hind's Solar System, p. 175.

covered, the orbits of six or seven hundred comets, some of brief period, have been ascertained;—and it has been computed that hundreds of thousands of these mysterious bodies wander through our system. There is no reason to think that all the primary planets, which revolve about the sun, have been discovered. An indefinite increase in the number of asteroids may be anticipated; while outside of Neptune, between our sun and the nearest fixed star, supposing the attraction of the sun to prevail through half the distance, there is room for ten more primary planets, succeeding each other at distances increasing in a geometrical ratio. The first of these will unquestionably be discovered as soon as the perturbations of Neptune shall have been accurately observed; —and with maps of the heavens, on which the smallest telescopic stars are laid down, any one of them may be discovered much sooner.*

But it is when we turn our observation and our thoughts from our own system, to the systems which lie beyond it in the heavenly spaces, that we approach a more adequate conception of the vastness of Creation. All analogy teaches us that the sun which gives light to us is but one of those countless stellar fires which deck the firmament, and that every glittering star in that shining host is the centre of a system, as vast and as full of subordinate luminaries as our own. Of these suns,—centres of planetary systems,—thousands are visible to the naked eye, millions are discovered by the telescope. Sir John Herschell, in the account of his operations at the Cape of Good Hope,† calculates that about five and a half millions of stars are visible enough to be *distinctly counted* in a twenty foot reflector in both hemispheres. He adds that "the actual number is much greater, there can be

* Leverrier, *Compte Rendu*, 5th Oct. 1846, p. 659. Proceedings of American Academy of Arts and Sciences, Vol. I. p. 178.

† Results of Astronomical Observations made during the years 1834–8, at the Cape of Good Hope, p. 381.

little doubt." His illustrious father estimated on one occasion that 125,000 stars passed through the field of his forty foot reflector in a quarter of an hour. This would give 12,000,000 for the entire circuit of the heavens, in a single telescopic zone; and this estimate was made under the assumption that the nebulæ were masses of luminous matter not yet condensed into suns.

These stupendous calculations, however, form but the first column of the inventory of the universe. Faint white specks are visible even to the naked eye of a practised observer in different parts of the heavens. Under high magnifying powers, several thousands of such spots are visible, — no longer, however, faint white specks, but many of them resolved by powerful telescopes into vast aggregations of stars, each of which may with propriety be compared with the milky way of our system. Many of these nebulæ, however, resisted the power of Sir Wm. Herschell's great reflector, and were accordingly still regarded by him as masses of unformed luminous matter. This, till a few years since, was perhaps the prevailing opinion, — and the nebular theory filled a large space in modern astronomical science. But with the increase of instrumental power, especially under the mighty grasp of Lord Rosse's gigantic reflector and the great refractors at Pulkova and Cambridge, the most irresolvable of these nebulæ have given way; and the better opinion now is, that every one of them is a galaxy, like our own milky way, composed of millions of suns. In other words, we are brought to the bewildering conclusion, that thousands of these misty specks, the greater part of them too faint to be seen by the naked eye, are, not each a universe like our solar system, but each a "swarm" of universes of unappreciable magnitude.* The mind sinks overpowered by the contemplation. We repeat

* Humboldt's Cosmos, Vol. III. p. 44, Otté's Translation.

the words, but they no longer convey distinct ideas to the understanding.

But these conclusions, however vast their comprehension, carry us but another step forward in the realms of sidereal astronomy. A proper motion in space of our sun and of the fixed stars, as we call them, has long been believed to exist. Their vast distances only prevent its being more apparent. The great improvement, which has taken place in instruments of measurement within the last generation, has not only established the existence of this motion, but has pointed to the region in the starry vault, around which our whole solar and stellar system, with its myriad of attendant planetary worlds, appears to be performing a mighty revolution. If, then, we assume that outside of the system to which we belong, and in which our sun is but a star like Aldebaran or Sirius, the different nebulæ of which we have spoken, thousands of which spot the heavens, constitute each a distinct family of universes, we must, following the guide of analogy, attribute to each of them also, beyond all the revolutions of their individual attendant planetary systems, a great revolution, comprehending the whole; while the same course of analogical reasoning would lead us still further onward, and in the last analysis, require us to assume a transcendental connection between all these mighty systems, — a universe of universes, circling round in the infinity of space, and preserving its equilibrium by the same laws of mutual attraction, which bind the lower worlds together.*

It may be thought that conceptions like these are calculated rather to depress than to elevate us in the scale of being; that banished as he is by these contemplations to a corner of creation, and there reduced to an atom, man sinks

* For popular views of the present state of science in the department of sidereal astronomy, see Sir John Herschell's Outlines, Part III.; Himmelskunde volksfasslich bearbeitet von M. A. Stern, pp. 258–319; and Etudes d' astronomie Stellaire, par F. G. W. Struve.

to nothingness in this infinity of worlds. But a second thought corrects the impression. These vast contemplations are well calculated to inspire awe, but not abasement. Mind and matter are incommensurable. An immortal soul, even while clothed in "this muddy vesture of decay," is in the eye of God and reason, a purer essence than the brightest sun that lights the depths of heaven. The organized human eye, instinct with life and spirit, which, gazing through the telescope, travels up to the cloudy speck in the handle of Orion's sword, and bids it blaze forth into a galaxy as vast as ours, stands higher in the order of being than all that host of luminaries. The intellect of Newton, which discovered the law that holds the revolving worlds together, is a nobler work of God than a universe of universes of unthinking matter.

If still treading the loftiest paths of analogy, we adopt the supposition, — to me I own the grateful supposition, — that the countless planetary worlds which attend these countless suns, are the abodes of rational beings like man, instead of bringing back from this exalted conception a feeling of insignificance, as if the individuals of our race were but poor atoms in the infinity of being, I regard it, on the contrary, as a glory of our human nature, that it belongs to a family which no man can number of rational natures like itself. In the order of being they may stand beneath us, or they may stand above us; *he* may well be content with his place who is made "a little lower than the angels."*

Finally, my friends, I believe there is no contemplation better adapted to awaken devout ideas than that of the heavenly bodies; no branch of natural science which bears clearer testimony to the power and wisdom of God, than that to which you this day consecrate a temple. The heart of the

* For some interesting views of the controversy which had its origin in the ingenious Essay "of the Plurality of Worlds," see Professor Baden Powell's "Essays on the Spirit of the Inductive Philosophy, the Unity of Worlds, and the Philosophy of Creation."

ancient world, with all the prevailing ignorance of the true nature and motions of the heavenly orbs, was religiously impressed by their survey. There is a passage in one of those admirable philosophical treatises of Cicero, composed in the decline of life, as a solace under domestic bereavement and patriotic concern at the impending convulsions of the State, in which, quoting from some lost work of Aristotle, he treats the topic in a manner which almost puts to shame the teachings of Christian wisdom: —

"Praeclare ergo Aristoteles, 'si essent,' inquit, qui sub terra semper habitavissent, bonis et illustribus domiciliis quæ essent ornata signis atque picturis, instructaque rebus iis omnibus, quibus abundant ii qui beati putantur, nec tamen exissent unquam supra terram; accepissent autem fama et auditione, esse quoddam numen et vim Deorum; deinde aliquo tempore, patefactis terræ faucibus, ex illis abditis sedibus evadere in hæc loca quæ nos incolimus, atque exire potuissent; cum repente, terram, et maria, cœlumque vidissent; nubium magnitudinem, ventorumque vim cognovissent, aspexissentque solem, ejusque tum magnitudinem pulchritudinemque, tum etiam efficientiam cognovissent, quod is diem efficeret, toto cœlo luce diffusa; cum autem terras nox opacasset, tum cœlum totum cernerent astris distinctum et ornatum, lunæque luminum varietatem tum crescentis tum senescentis, eorumque omnium ortus et occasus, atque in æternitate ratos immutabilesque cursus; hæc cum viderent, profecto et esse Deos, et hæc tanta opera Deorum esse arbitrarentur."*

"Nobly does Aristotle observe, that if there were beings who had always lived under ground, in convenient, nay, magnificent dwellings, adorned with statues and pictures, and every thing which belongs to prosperous life, but who had never come above ground, — who had heard, however, by

* Cicero de Natura Deorum, Lib. II. § 30.

fame and report, of the being and power of the gods,—if at a certain time, the portals of the earth being thrown open, they had been able to emerge from those hidden abodes to the regions inhabited by us; when suddenly they had seen the earth, the seas, and the sky; had perceived the vastness of the clouds and the force of the winds; had contemplated the sun, his magnitude and his beauty, and still more his effectual power, that it is he who makes the day by the diffusion of his light through the whole sky; and when night had darkened the earth, should then behold the whole heavens studded and adorned with stars, and the various lights of the waxing and waning moon, the risings and the settings of all these heavenly bodies, and their courses fixed and immutable in all eternity; when, I say, they should see these things, truly they would believe that there are gods, and that these, so great things, are their works."

There is much by day to engage the attention of the observatory; the sun, his apparent motions, his dimensions, the spots on his disc, (to us the faint indications of movements of unimagined grandeur in his luminous atmosphere,) a solar eclipse, a transit of the inferior planets, the mysteries of the spectrum; all phenomena of vast importance and interest. But night is the astronomer's accepted time; he goes to his delightful labors when the busy world goes to its rest. A dark pall spreads over the resorts of active life; terrestrial objects, hill and valley, and rock and stream, and the abodes of men disappear; but the curtain is drawn up which concealed the heavenly hosts. There they shine and there they move, as they moved and shone to the eyes of Newton and Galileo, of Keppler and Copernicus, of Ptolemy and Hipparchus; yea, as they moved and shone when the morning stars sang together, and all the sons of God shouted for joy. All has changed on earth; but the glorious heavens remain unchanged. The plough passes over the site of mighty cities, the homes of powerful nations are desolate, the languages they spoke are forgotten; but the stars that shone for them are shining for us; the same eclipses run their steady cycle; the same equinoxes call out the flowers of spring and send the husbandman to the harvest; the sun pauses at either tropic as he did when his course began; and sun and moon, and planet and satellite, and star and constellation and galaxy, still bear witness to the power, the wisdom, and the love which placed them in the heavens, and upholds them there.