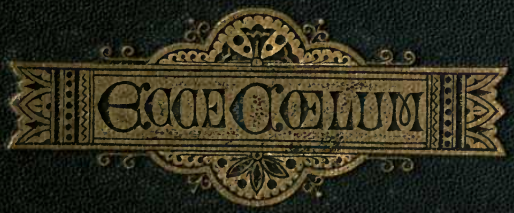

D. C. Gilman.

ECCE CŒLUM;

OR,

PARISH ASTRONOMY.

In Six Lectures.

BY A CONNECTICUT PASTOR.

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To

REV. W. A. STEARNS, D.D., LL.D.,

PRESIDENT OF AMHERST COLLEGE,

THIS VOLUME

OF PARISH LECTURES ON ASTRONOMY IN THE INTEREST OF RELIGION,

IS RESPECTFULLY DEDICATED

BY

THE AUTHOR.

omy, as a whole, from it than I ever got before from all other sources, — more than from Enfield's great book, which I once carefully worked out, eclipses and all.

"I trace the progress made, and the methods of the same, and seize on the exact status of things at the point now reached."

From the Bibliotheca Sacra.

"This is a remarkable book, — one of the most remarkable which has proceeded from the American press for a long time. It lifts the reader fairly into the heavens and unveils their glories. The presentation is very full though concentrated, very clear and animating, — with a command of language and a glow of eloquence which is quite extraordinary. The last lecture is hardly less than a Te Deum. The only adverse criticism which, on reading the preparatory lecture, we were inclined to make, was, that the almost impassioned eloquence with which it opened would have been more impressive further on, and after the imagination had been excited by the facts. But, after finishing the last Lecture, we could not wonder that a mind so full of the great facts, and of the emotion which they necessarily kindle, should, on seeing his own parish charge assembled to listen, break forth in strains which none but a mind fully roused by his theme and his audience would have been able to utter. No person can read through this volume without mental exaltation, and a conviction of the peculiar ability of the author."

From the New Englander.

"It presents an admirable *résumé* of the sublime teachings of Astronomy, as related to natural religion, — a series of brilliant pen-photographs of the Wonders of the Heavens, as part of God's glorious handiwork. The first five lectures pass the science in rapid review; the last treats of the Author of Nature, as related to its leading features. There is not a dry page in the volume, but much originality and vigor of style, and often the highest eloquence. It is, withal, evidently by an author at home in his subject, not "crammed" for the task. It affords a fine example of what an intelligent pastor can do, outside of his pulpit, towards training an intelligent people, and by imparting to them Nature's

teachings, leading "through Nature up to Nature's God," — the God of Revelation as well. To such a book the author need not hesitate to affix his name."

From Rev. A. P. Peabody, D.D., LL.D., Preacher to Harvard University, and Plummer Professor of Christian Morals.

"Permit me to thank you for a work in which you have effected a rare union of scientific accuracy, eloquent diction, and rich devotional sentiment. It is attractive, instructive, and edifying. It appears at a time when science needs, as never before, to be redeemed and sanctified by faith in Him, in whom are hidden all the treasures of wisdom and knowledge. And, best of all, it does not make Religion cringe to Science, but maintains her in that queenly status which is the only position she can hold. The book must do great good, and I heartily congratulate you as its author."

From Rev. S. H. Hall, D.D.

"Ecce Cœlum is much more than a book-success. It will be honored as a most timely and admirable treatise to put into the hand of thoughtful young people, to 'turn off their minds from vanity,' and lead them to God."

From the New-York Evangelist.

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From the Religious Herald.

"A New Book, and one that is a book, worth its weight in gold or diamonds, for it is full of gold and precious gems, — diamonds of law and fact, — truths beaming with celestial light. I

speak of 'Ecce Cœlum,' from the pen of Rev. ENOCH F. BURR, D.D., of Lyme, Conn., published by Nichols & Noyes, Boston, a duodecimo of 198 pages. Mr. Burr modestly signs himself 'A Connecticut Pastor,' but some college has rent the vail and written out his full name, and added to it a D.D. So much the better for Connecticut and for the world. Such light as the book contains ought not to be under a bushel.

"These six Parish Lectures are a masterly, vivid, easy, sublime presentation of the enchanting facts of Astronomy. They are adapted to all classes, — the learned and the unlearned. The astounding glories of the skies are tempered to our humble eyes.

"Let all read the book, old and young. Let it be found in every school, in every library, and in every home where wisdom is invoked. Read it, and you will exclaim, what glorious light it sheds from the throne of God upon the lonely pathway of man!"

From C. H. Balsbaugh, of Pennsylvania.

"It is certainly a wonderful little book. How the world shrinks into an atom as we follow the lofty soarings of the 'Connecticut Pastor.' I never knew rightly what Dr. Young means by saying, 'an undevout Astronomer is mad;' but I now see and feel the power and beauty of the expression. Such a book cannot be read without laying upon us the responsibility of a new charge from heaven. After contemplating such grandeur, we instinctively exclaim, 'What is man that Thou art mindful of him?'"

From Hon. S. L. Selden, Late Chief Justice of New York.

"A beautiful book. I admire it for the elegance of its style, as well as for the lucid and able manner in which it presents the noblest of the sciences. It will prove, I think, very valuable, not merely for the knowledge it communicates, but as suggestive of a line of noble and elevated thought. And I am much pleased to see from the numerous notices which have come under my observation that my estimate is confirmed by many persons of the first capacity for judging. To have written a work which receives and deserves such *very* high praise from scholars and men of science cannot but be a source of great gratification to the author."

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I.

PREPARATORY.

I. Preparatory.

FIRST LECTURE.

PREPARATORY.

ASTRONOMY, the science of the stars, does not limit itself to those bright points in the vault of evening which are commonly called stars, but treats of the Sky with its whole star-like belongings — Sun, Moon, Planets, Comets — whatever of this general nature reveals itself in the entire round Heavens.

What is the use of Astronomy? Had this question been asked a few centuries ago, most intelligent persons would have said that its chief use was to aid astrology. Somehow, men had conceived the idea that the fortunes of individuals and nations were bound up with the aspects and places of the heavenly bodies, and could be predicted from them. It was universally believed that, could the places of certain bodies in the sky at the birth of any person be well ascertained, it would be possible to infer the general character of his lot in life and its critical periods. Here was grand motive for study.

Men have always had great taste for being prophets and hearing prophets; so, with infinite zeal and pains, they watched the mazy heavens, and, out of such glittering fractions of information as they could gather, built up, as their chief use, a stupendous system of fortune-telling whose Twelve Houses, whose Lords of the Ascendant, whose Horoscopes and Nativities, were the business of sages, and the trust of monarchs and the people for thousands of years.

It is well that we have some better reason than its astrological uses to give for studying the Science of the Sky.

See where the sun, with face of insufferable splendor, goes swimming through the day; see where the soft and silver moon, with fleets of stars, goes swimming through the night! What an eloquent silence! There they shine and move, perhaps wonderfully achieve — hosts upon hosts; but there is no celebrating pomp of sounds, only an all-embracing pomp of silence — not a whisper, not a rustle, through all the vasty dome. Our dinned ears and hearts are soothed. Our petty cares and excitements are hushed. Both body and soul are insensibly calmed and refreshed as we gaze into the immeasurable stillness.

Was ever so noble a sight! What kindly interweavings of the great and the lovely — what gorgeous competitions and combinations of the majestic and the beautiful — and all steeped in the

grave glory of immemorial and supreme antiquity. The sky does not look old. Other books show sad marks of the passing years. Their pure white sullies. Their varnished, sharp-cut characters grow dull and vague. Scars and molds and odors of decay gather upon them. Not so with this pageant book opened above us, this illuminated missal of the heavens. It shows a page as delicately fair and fresh as if it had just come from the hands of its Author. And yet it is the world's ancientest heir-loom, the issue of the eldest dawn: and, as we look upon its broad and pictured page, we are reverently aware that the same shining scripture met the gaze of famous empires long since dead and buried; of those old men of renown whose forms loom gigantically on the outskirts of tradition; of him, hoarest ancient of all, the Old-Testament Adam. It is a joy and an exaltation to peruse such a Natural Bible.

And then it is so accessible! Not, like some rare old volume of price, hid away from the people at large in piles of granite architecture; railed off heavily from the curious handling and close inspection of most of such as are allowed to roam the stately halls; permitted to unclasp only under the careful hands and cultured eyes of sages and princes — not such is this azure volume above, printed and pictured in silver and gold. It is a book for the people. Its outspread page invites study from all quarters, by day and

by night. One can feast his eyes on it as freely as another. If it has any valuable secrets, any precious wisdoms in it, one is just as welcome as another to do what he can toward finding them. God permits no censorship. His printing is a true publishing. With both hands he has issued his astronomy; has put it in characters large and shining enough to be within the range of all eyes; has opened it as wide as wide can be, and laid it across the sky's fair face for all who choose to examine, stand they at palace-gates, stand they at cabin-doors, stand they in the silent domes of sky-piercing observatories, stand they on the rattling mid-road of affairs. All classes welcome — welcome to that divine calm, to that refined and exalting pleasure, to that jubilee of sight and poetry and art, to that feast of the gods!

And not only to this sensuous and æsthetic banquet which lies spread on the golden surface of things for all who have eyes and souls, but to the more interior and recondite stores of which these others are mere tokens and crumbs. For the sky is not only an accessible book, but, in these last days, an interpreted one. It has been translated out of its aboriginal hieroglyphics, put into the world's vernacular, done into alphabet even, as to its most essential facts. The interpretation was hard. Sometimes it seemed as if it would never be made. It actually took great men, and many of them, to make it; and many a

long age crept away while the work was being done. But, lo! done it is at last; and the results, though not the methods, are now level with the commonest men. And they are exceedingly serviceable results. Once, men could not see an eclipse or a star with a tail to it without inferring pestilence and war; could not even see a bloody sun or shooting star without fearing national disaster and the fall of thrones. But now humanity no longer falls a-trembling at the signs of heaven. The progress of astronomical science has freed us from our superstitious terrors. We leave such panics to centuries ago and the heathen. Thanks to the sages who have interpreted to us the Sibyls of the sky! Thanks to them, too, that commerce no longer rows her scant and Liliput shipping in timid adventure within her native creeks, and along her native shores. To the science of the stars we owe the safety and audacity with which unlimited canvas now stretches across the widest seas and darkest nights. By the improvements it has been the means of introducing into mathematics and observation, it has raised the whole body of our art and science; in fact, created large portions of each. Scarcely a branch of business or knowledge, however humble, or however high, but is debtor, in one way or another, to astronomical investigations. Astronomers first taught men the art of questioning Nature. They were the first inter-

preters of her that deserved the name, the first to give dazzling and triumphant examples of the way of extorting secrets from her close-fisted keeping. In education, also, astronomy has been of most material service. A large and generous culture of the mind requires familiarity with a wide variety of ideas. We need to be trained to refined distinctions, to subtle analyses, to acuteness of thought; and for this purpose other sciences will answer better than astronomy. But we also need, still more, culture in breadth and dignity and gravity of ideas, in comprehension and solidity of understanding, in elevation and durable glow of imagination and character; and, for this purpose, no branch of secular knowledge can compare with the science of the stars. This science is worth more than all the fictions and poems in the world as a judicious cultivator of the imagination and corrector of insipidity and tameness of character. It is universally admitted to be the sublimest of the natural sciences. It is a poem as well as a science — the best example we have of polished completeness in a science, and the noblest specimen we have of an epic poem. Not Milton, not Homer, ever sang so sweetly and loftily as do the chief theorems of astronomy. And certainly, if one would get just ideas of the grandeur and possibilities of the human mind, in no way could he better accomplish his purpose than by noticing what great astro-

nomical problems that mind has grappled with and conquered. It has been the war of Jupiter with the Giants. When we look at the mighty secrets that men have wrested out of that starry page above us, we say softly and reverentially to ourselves, "In the image of God made he them." We also feel that what man has done man can do. We are encouraged for the future of science, the future of art, the future of every thing requiring great endowments in man. But, after all, the most interesting and useful thing about astronomy is the illustration it pours on the attributes and glory of the Supreme Being. Let it be repeated, that ancient sentiment, "An undevout astronomer is mad." If one can thoughtfully pace up and down the star-sown fields of astronomy and not conceive a feeling of religious awe, as in the presence of Incomprehensible Almightiness, he must be a rare man, a sinner above all the Galileans. The fullest force of this inspired saying, "for the invisible things of Him are clearly seen, being understood by the things that are made, even his eternal power and godhead," — I say, the fullest force of these words is only felt by him whose thoughts, leaving the diminutive objects of this world, have gone voyaging through the inexhaustible wonders of the firmament and gazed intelligently on the files of that infinite armada of luminaries, which, in exquisite harmony and solemn pomp, cruise up and down yonder shoreless ocean of the heavens.

Astronomy is universally admitted to be the most ancient of all the natural sciences. How ancient none can tell. Neither history nor tradition carries us back to its beginning. We can learn nothing of its founder or founders. Their very names are lost in the darkness of the primal ages. At the time when we get our first clear view of the science, viz. two or three thousand years before Christ, it had already made very considerable progress. Some say that Chaldea, with its beautiful atmosphere, was the native country of astronomy; others stand up stoutly for Egypt, "mother of sciences"; while still others think favorably of the claims of India, with its most ancient of all astronomical tables, the tables of Tirvalore, and its most ancient and studious Brahmins. Who know? Not even those persons who have taught that the cradle stood in this country by claiming that here stood the cradle of the human race — that fossils of the human period in the United States go back to a remoter antiquity than those in any other part of the globe! Astronomy was cultivated in very remote times — hundreds and perhaps thousands of years before the Christian era — by the Chinese as well as by the East-Indians, Egyptians, and Chaldeans. Since the time of reliable history, however, the science has been in a state of decay, if not extinction, among most of these nations. With some it has long been one of the totally lost sciences.

We look in vain for a living astronomy through all the countries of the East. We find nothing but a fossil, and a mutilated fossil at that. Civil troubles, with other causes perhaps, killed and buried it before the historic period in all those remoter Oriental lands. In Egypt, however, and subordinately in Greece, the science continued to live and occasionally grow till within times quite modern. The world will not willingly let die such names as Thales, Pythagoras, Hipparchus, Ptolemy; nor the glory of that famous Alexandrian school, which, from three hundred years before Christ, till the sack of Alexandria and the destruction of its famous library, in the seventh century, continued to toil away, and not without success, on the heavens. That terrible vandalism that destroyed the garnered wisdom of so many centuries suppressed astronomical culture in the West for nearly a thousand years. The old Romans were fighters, never astronomers. Their *disjecta membra*, the middle ages, were fighters, never astronomers. Meanwhile the cast-away science found a home among the Arabs. At Bagdad, under the caliphates of the Abassides, arose a new Augustan age for all sorts of learning. Equally enlightened and powerful, those splendid monarchs gathered about themselves the cultivators of knowledge from every quarter, and spared neither pains nor gold to make their capital the focus of the world. And

they succeeded. While it was unrelieved midnight in Europe, it was midnight lit up by calcium lights in Arabia. Immense attention, in particular, was given to astronomy; and the mere names of those Saracenic philosophers who cultivated this and other branches of liberal knowledge would fill a volume. Moreover, it was from the splendid and enlightened kingdom which the Arabs established in Spain that astronomy was again set on her feet in the rest of Europe, at the beginning of the sixteenth century, after well nigh a millennium of exile. After all, the amount of real discovery in the heavens made, up to this time, by all these illustrious men and schools, of various nations, for thousands of years, was comparatively small. Many a single year since has done more for astronomy than was done by all the many thousands of years before. The fact is, the old astronomers were destroyed by their theories and visionary philosophies. Instead of carefully observing Nature and drawing their systems from it, most of them first arbitrarily formed their systems and then endeavored to interpret Nature in consistency with them. Like many people now, they scorned to begin at the beginning. They wanted to build their house from the roof downward, instead of building it from the foundation upward; wanted to start with Euclid and Homer and figure their way back to a knowledge of the alphabet; wanted

to start with the broadest generalizations of science and so descend on particulars, like Plato, their great master or representative. In consequence very little was accomplished, considering the prodigious time and labor expended. It was not till Prussian Copernicus and his immediate successors cast off the old theories and way of studying Nature, that astronomy can be said to have fairly begun her triumphant career. The incubus once lifted, she then, under the lead of such men as Tycho Brahe, Kepler, Galileo, Newton, went forward with gigantic strides. Up to the present time, it has been one incessant tramp and thunder of discoveries. Scarcely would one great truth flash down from the sky before men's attention would be called to another. Much of the time, indeed, these truths have come in showers and set the whole sky ablaze. It is not much exaggeration to say that the heavens, instead of raining stars upon us once every November, are raining them nearly the whole time. Like the tributaries of some Mississippi or Amazon, contributions have flowed into the main astronomical current from every quarter and Christian land. The French (a wonderful nation for every thing save religion and self-government) have particularly distinguished themselves. Since Newton, no names in science so glorious with achievement, to none will a grateful posterity so freely decree triumphs, as to those of Clairaut, La Grange,

La Place, and Arago. The English-speaking race have also found laurels growing in the sky and have liberally plucked them — witness Flamstead and Halley and Bradley and Maskelyne and the two Herschels. For Germany and Russia, are the great names of Bessel and Argelander and Struve and Mædler — names inseparably connected with some of the most recent and dazzling successes of astronomy. They have added, not cities, but provinces, to her empire. Altogether, the astronomers of the last three hundred years have given us the most extensive, sublime, and complete science to be found in the world.

And by what means were these grand results reached? The naked eye has done something — done much. In remote times, men had nothing else with which to explore the heavens: but this, with the help of the pure Chaldean air and leisurely shepherd life; this, with the help of the perpetually cloudless Egyptian sky and the free, secluded life of the cultured and inquisitive priesthood, was sufficient to lay the foundations of astronomy. Even to this day, the unaided eye has made, and it need not despair of still making, discoveries in the heavens. Next, astronomy is indebted to artificial instruments — to telescopes, and instruments for measuring angles. Contrivances for measuring the angular distances of the heavenly bodies from each other were first used about three hundred years before Christ, at

Alexandria. They were very rude; so much so, that Hipparchus and Ptolemy considered it a great achievement to measure angles of $10'$ — about one-third of the moon's diameter as it appears to the eye. But even such rude approximations to the places of the stars accomplished several discoveries, and gave the charts and catalogues which have contributed to still more and greater discoveries in modern times. Tycho Brahe made great improvements on the instruments of preceding astronomers. He found himself able to measure angles of $10''$ — an accuracy sixty times greater than Hipparchus could command. Hence another instalment of discoveries. At the present time we have goniometers of wonderful beauty and exactness — almost an equal feast to the eye of the poet and to that of the mathematician — enabling us, by management, to reach an accuracy ten thousand times greater than was obtained by Tycho with his improved instruments three hundred years ago; enabling us to measure celestial arcs no larger than a thousandth part of a second. It is this last style of accuracy that has, within a few years, enabled us to find the distances from us and from each other of some of the fixed stars, so called, as well as other results scarcely less wonderful. But these exact instruments and their splendid contributions to astronomy, are largely due to two other means of discovery, viz. observatories and optical glasses. To secure firm sup-

port for instruments, to lift them above the vapors that more or less always lie along the surface of the ground and give to them a large and unobstructed horizon, massive and lofty towers have been built. On such a tower — Uraniberg, he called it — Tycho placed his instruments and made his discoveries. On such towers, numbered by hundreds and fitted up like palaces for every sort of celestial observation, a thousand astronomers now watch out the night all over Christendom — at Paris, at Greenwich, at Pulkova, at Washington. Observatories are the fulcrums of astronomy. They are the war-towers from which we can best attack the skies. If the Tower of Babel had only been designed for such use, as certain incautious persons have suggested, there would have been much good sense in it!

At Florence, in the Grand-Ducal palace, there is a room called the Temple. The walls are inlaid with marble and jasper. The ceiling glows with superb frescoes. In niches about the apartment are disposed numerous marble busts — portraits — in the best style of recent art. At the center, the gem and significance of the whole, stands a life-size statue — also a portrait — in whose snowy marble features one recognizes, not only the majesty of art, but also the majesty of a well-known sage whose single name is sufficient riches for a country. Here, in 1840, met the Italian men of science to dedicate the proudest

cabinet of the Medici to the great memory of Galileo Galilei, whose statue that is, whose disciples' busts those are, whose leading life-events that glowing ceiling commemorates — Galileo, the first telescopic explorer of the heavens. Well did he deserve the honor. His single renown more honors his native city than do all her grand dukes, than would permanent rank as capital of Italy. And here, in a press by the wall, is the very telescope with which he made his discoveries — two curved glasses rudely fastened in a rude tube, all made with his own hands. With this simple instrument he created a new era in astronomy. With it he poured on the age such a succession of wonders that foolish Rome feared that the immovable foundations of Holy Scripture would all be swept away by the deluge of innovations. As if her interpretations of the Bible were the Bible itself! Since then, the telescope has been bravely plucking laurels from the sky almost incessantly. Made reflecting; made achromatic; enlarged from an object-glass of two inches to one of eighteen, and from a speculum of six inches to one of six feet; equatorially mounted, with all the appliances for easy motion, exact adjustment, and extremest nicety of measurement; planted in palatial observatories where all the heavens look in at the revolving dome and where scarcely a tremor of storms can find its way through the solid masonry; supported on either hand by Photo-

graphy and Telegraphy — in short, the Great Refractor of Pulkova or the Great Reflector of the Earl of Rosse — the telescope of late years is still pushing incessant conquests in every direction through the sky. Formerly, the telescope was one; now it is *e pluribus unum;* and from thousands of Uranibergs, public and private, the wonder-working tube is nightly run out against the sky, till the civilized world fairly bristles like a battery in time of active war; and competing observers, under the spur of a generous emulation, almost nightly bring down upon the earth some mighty truth, or the promise of one, by their voiceless celestial artillery.

Not long after the invention of the telescope, the means of astronomical investigation received another accession of at least quite as great importance. I refer to that branch of the mathematics called by Newton, one of its inventors, Fluxions, but now universally known among scientific men under the name of the Differential and Integral Calculus. It is a species of higher algebra; and its peculiarity consists in considering all finite quantities as expressible by the ratio of two infinitely small quantities to each other. It is found that this mode of considering quantities has in it a mysterious and subtle energy for the resolution of problems of the higher order, beyond any thing known. It is a natural magic. It is the quintessence of dynamics. The old geom-

etry, both synthetic and analytic, is a mere infant compared with it. No one is now considered half equipped for astronomical research unless he can wield this splendid instrument. Taking certain facts given by observation, together with the Newtonian law of gravitation that every particle of matter attracts every other particle with a force proportioned directly to its own quantity of matter and inversely to the square of the distance between them — taking these as its fulcrum, the Calculus has proved itself more than the lever of Archimedes; for that moves only one world, this moves all the heavens.

To see the feats of this Calculus makes one think of days of enchantment. I have a supreme confidence that none of you have ever heard this Arabian history of what anciently happened to one of the Genii. It seems that this good monster, who was as tall as a mountain and as strong as an earthquake, had, on a certain occasion, amused himself by endeavoring to squeeze his huge figure into a little enchanted black bottle. At last he succeeded. Suddenly the cap flew down and he was caught. Some thousands of years afterwards, a poor man, while at his work one day and thinking how hard it was with his best efforts to make a living, stumbled on this same little bottle. "Let me out — let me out!" cried the bottle in a half-suffocated whisper. "Can't do it," quoth the man, at once aware of

his good fortune, — "can't do it." "I will do any thing you want if you will," begged the prisoner. "Will you take away that great mountain between me and the city — will you turn my little tent into a palace — will you fill it with gold and precious stones —will you promise by all that is sacred to Genii, by the Prophet and Alcoran and Allah?" "Yes, I promise." After some difficulty, the man managed to find out the secret of the spring-cap, and lifted it; when, swift as an arrow, out rushed a puff of blue vapor, which gradually expanded till, as tall and broad as Mount Shahak, it took the form of a winged man. Without any ado, the monster took up the mountain in his arms and walked off with it a few steps, say a hundred miles or so, and threw it down in a valley behind Bagdad, where he who chooses can see it at this day. Then stepping back, he caught up the little tent and threw it up into the sky out of sight, saying, "Come down great, come down precious." In a few minutes, a cloud came settling down on the spot; and, as it slowly broke away, the man discovered minarets and towers and, at last, a whole gorgeous palace of marble, fit for the Leader of the Faithful himself. Then the Genius plucked a leaf from a majestic palm that waved proudly by the portal and wrote certain strange characters on it with his finger. Tearing it into small pieces, he puffed them away in every

direction with his breath. Immediately, long lines of Ethiopian slaves were seen coming up from all quarters, with immense stuffed sacks on their shoulders (I suppose twelve men in these degenerate days could scarcely lift one of them); and, as each entered the palace and laid his sack on the floor, he laid himself down also by the side of it and became another sack as large and full as that he had brought. In a short time, the palace was full, from foundation to roof. "Come and see," said the Genius. Lo, gold Alraschids, Almansors, and Motassems! Lo, carbuncles and sapphires and diamonds filled every apartment! "Have I kept my promise — am I free?" — "Ay;" said the enraptured fellow, "and well have you deserved your liberty." — "To tell the truth," quoth the spirit, "I have been so long in that little black bottle that I think I had rather stay there than anywhere else. When you want me you will know where to find me." So, without any more ceremony, he doubled himself up and squeezed into the bottle again. Was not his name Radib? Was not that poor man the same Emir Alabdes by whom the Caliph Motassem (for whom Allah be praised), with ten thousand of his attendants, was so sumptuously entertained at his marble palace, in the 180th year of the Hegira?

I say, it makes one think of such an Arabian Nights' story, when he looks at some of those lit-

tle equations out of which Clairaut and La Place and others have managed to evoke such prodigious dynamics as have sufficed to enrich themselves and their race with uncounted treasures of fame and truth; as have sufficed to remove mountains from the path of astronomy, and convert her humble tent into a spacious palace filled with unprecedented gems of the plundered sky. How much does yonder star weigh? When will yonder hairy star come back? Suppose five worlds launched in vacancy from a given position, with given directions and velocities, where will each be twelve thousand years hence? Such questions as these which men would once have despaired of answering, and even greater questions the terms of which cannot properly be assumed as intelligible at this point, the Calculus has conquered and dragged in triumph at its chariot-wheels. And still this prince of good Genii is at the service of astronomers. He does not care for his liberty. He still likes to take up headquarters in the little black bottle of a differential equation. When his friends want something great done they know where to find him. And I should not be surprised to see the day when I can tell of new feats of his doing, quite as prodigious as any yet recorded. Do not doubt it — he is as strong as ever. The race of Eulers, Newtons, and La Places, is not yet dead. Gifted men are busily learning the secret of the spring-cap. And, some

fine morning, men shall read on the bulletin boards of science of new mountains removed, new palaces built, new whole commissariats of golden and diamond truths established for astronomy by the redoubtable Radib of the Differential and Integral Calculus.

II.

THE SKY.

II. The Sky.

SECOND LECTURE.

THE SKY.

I AM to explain what discoveries have been made in the distant sky. To do this to the best advantage, we must have a picture of the sky, with its leading aspects and names, fresh in our minds.

So let us imagine this structure unroofed, and, indeed, well taken down on all sides. And, to-night, let us further imagine that some tall Genius is kind enough to brush away with his besom the envious clouds — those ancient and unutterable enemies of the astronomer. We seem to be at the center of an immense hollow half-globe, on the distant surface of which appear the heavenly bodies. If it were day, we should see on that remote concave the yellow sun: it being night, we see, instead, a multitude of stars and the moon with its silver crescent. Watch the host for a little behind some building, and you may satisfy yourself that they are all in motion towards the west; that is to say, are all revolving about a

line drawn through where you are sitting and a point due north, but elevated about 40° above the horizon. Notice that very bright white star low in the west: that is Venus, named after the Greek and Roman goddess of beauty. Yonder, almost overhead, is another star, of scarcely inferior brightness but of more masculine hue: that is Jupiter, named after the king of the classical divinities. East of the zenith, about one third of the way down, you may perceive a much smaller star of ruddy light — Mars by name — appropriately called from the bloody god of war. Do you see that small star, just visible to the naked eye, almost on the eastern horizon? Well, that is Saturn, named from the father of the principal gods, and sufficiently dim to represent one who is said to have had the very unfatherly and unhandsome trick of eating his own children. These stars, and many others which are never seen without a glass, are called planets, because they wander about greatly on the sky. Besides these, are certain other bodies, seen only occasionally, which are still greater wanderers — comets so-called, hairy stars — a denser part more or less bright, surrounded by a haze which often is found expanded into a pale streamer of prodigious length.

All others stars bear the name of fixed stars, because, to ordinary observation, there is little or no apparent change in their positions with

respect to each other. Some of these bodies are very conspicuous, real princes for shining, and so, from time immemorial, have been honored with proper names. There, for example, is one nearly as brilliant as Venus herself — Sirius — with a ray as frosty and keen as ever glanced from an iceberg; another, Aldebaran; another, Capella. Nearly half way up the northern heaven is a star by no means bright, but which has been on men's lips and in their eyes oftener than any other star whatever — the star by which ships have steered, and armies marched, and bondmen fled — the North Star. Count some twenty of the brightest of the fixed stars on the whole sphere: these astronomers call stars of the first magnitude. Count some sixty of the next brightest: these are of the second magnitude. Some two hundred of the next order of brilliancy: these are of the third. Six orders of magnitude are visible to the naked eye: ten orders more include those seen by the telescope.

Notice the unequal distribution of the stars on the sphere. Some are solitary, some in little groups and clusters, some in dense masses that resemble white clouds; while, among others, there seem no well-defined natural divisions — they seem sown broadcast and carelessly on the vault. That group of five stars forming the letter V is called the Hyades — rainy Hyades, said the ancients. That cluster a little further to the west

is the Pleiades—Job's Pleiades, with their sweet influences. And here, stretching across the whole hemisphere, like a white fog-bank with torches in it, is the well-known Milky Way which the old poets tell us was inadvertently made by Hercules when an infant. Other objects of the same general appearance are disclosed by the telescope in various quarters of the heavens — nebulæ, so they are called.

These are natural divisions of the heavenly bodies. There are others not so natural, called constellations. The ancients (no one knows how ancient they were), with not a little help from the moderns, pictured the celestial sphere all over with figures of men and brutes and other objects, so as to show almost as extensive a menagerie as was collected in Noah's ark: indeed, the very ark itself is there; at least Noah's dove, and we may reasonably suppose the ark to be not far off. There are bears and lions and domestic animals and birds and fishes and reptiles, interspersed with warriors and nymphs and centaurs and flying horses, all dovetailed into each other so as to include within their outlines nearly all the stars. If the leg or arm of a human figure could not be so disposed as to cover certain stars, a snake, under the sonorous name of Draco or Hydra, was slipped in to wind in and out till the crooked feat was accomplished. Very seldom any resemblance can be traced between the constel-

lations and the various objects after which they are called. But judge for yourselves. Around the North Star as a center, describe a circle that shall just touch the horizon. Within this circle are the Great and Little Bear, an immense Dragon, royal Cepheus with a crown on his head and a scepter in his hand, the helmed head and lifted falchion of Perseus, and on her chair, with a palm branch in her hand, queenly Cassiopeia. Would you think it? Around the point directly overhead, describe another circle that shall just touch the other. Within this new circle we have, towards the north, beauteous Andromeda, with fetters on her dainty hands and feet; west, Pegasus, the winged horse; over our heads, Aries the Ram; next east, a sort of celestial Spain — for there is shaggy Taurus in full career with horns leveled at giant Orion, who, sworded and belted, with a lion-skin in one hand and a club in the other, is just in the act of dealing the monster a rousing blow between the eyes that will undoubtedly make him see stars. Could you have thought it — such dignified personages, such delightful nymphs, such illustrious heroes, such magical creatures, such stirring tourneys and bull fights, all up and down the arches of the sky! However, these fanciful figures answer a very good purpose for classifying and describing the heavenly bodies. They distribute them into celestial nations and empires.

Provision is made for still further description of each celestial district, to any degree of minute accuracy that may be desirable. For many purposes, it is sufficient to tell what constellation a star is in. If we have occasion to be a little more precise, we can say in what part of the constellation it may be found, as in the neck of Taurus or head of Andromeda. To provide for still greater precision of statement, astronomers have named the stars in each constellation according to their apparent brightness. The brightest is called after the first letter of the Greek alphabet, Alpha; the next brightest, after the second letter, Beta; and so on through all the letters. When the Greek alphabet is exhausted, the Roman is used in the same way. If both alphabets are not sufficient to take account of all the stars, our common numerals are resorted to. Thus we speak of Alpha Leonis, a Virginis, 61 Cygni. But it is not always enough, in making a map of a country, to draw its boundaries and set down within them the various cities and towns of all sizes, in something like their relative positions: some geographical purposes require that you state also their longitudes and latitudes; that is to say, their distances due east or west, and their distances due north or south of a given point on the earth. So, for some astronomical purposes, it is not enough to bound a given constellation and set down its stars in nearly their

relative places, with their names. We require to know the longitude and latitude of each star. We must know how far it is from a certain great circle drawn northerly and southerly on the sphere, and how far also from another great circle drawn at right angles to the other. From very remote periods, astronomers have been engaged in getting this latter information. Hipparchus made out a catalogue of nearly all the stars visible to the naked eye at Alexandria, giving the latitude and longitude of each. Herschel, La Lande, Mayer, and others, have constructed similar catalogues, but giving the places of the stars with much greater accuracy.

We have before us a general picture of the celestial sphere, with the more usual names and classifications of the objects that shine upon it. I am now prepared to state what discoveries have been made. What is this seeming immense hollow globe of the heavens? People once thought that the appearance was reality — that they were surrounded at a great distance by an immense shell of crystal, to which all the heavenly bodies were fastened. At a later period, most scholars thought there were several of these spheres: each carrying heavenly bodies, and each having a motion peculiar to itself. But now we know that there is nothing of the sort above and around us. The celestial sphere is nothing but indefinitely extended space, made to appear colored at

times by the hue, and to appear rounded always by the shape, of our atmosphere. There is nothing solid yonder to which the celestial bodies can be attached. They are absolutely hung on nothing — though Milton ventures to take poetic license, and hang one orb, at least, by a golden chain. This idea of unsupported heavenly bodies was quite too hard for the remote ancients: they must have spheres, and, not a few of them, an elephant and a tortoise to hold up the earth and heavens. But, finally, it filtered through the apprehensions of people that such supporters must themselves need support quite as much as a star; also, that no one ever saw them, or otherwise credibly knew of their actual existence. So they were quietly dispensed with. And now nothing remains but the infinite space, which we certainly know to exist, and the stars which we certainly know to exist in it.

Popularly speaking, this great space which environs us on all sides, and contains the heavenly bodies, is empty. It is substantially a vacuum. The ancients said that Nature abhors a vacuum: if so, she has plenty of abhorring to do. There is no atmosphere pervading space: we could not breathe in its mid-intervals one single moment; there is nothing there that our senses could perceive. As we ascend from the earth, we find the air gradually become thinner; and La-Place has shown, that, after a few miles, it must

cease entirely. Beyond that point, very large solid bodies, though moving with enormous velocity, are found to encounter not the smallest perceptible resistance. Their places, as computed on the supposition that they move in a vacuum, are such as we actually find them. At the same time, there is reason to believe that the vacuum may not be absolutely perfect. Certain facts which have come to light in late years have convinced many astronomers that we must allow the existence of an exceedingly dilute form of matter pervading space. It is nothing that we could detect in the ordinary, sensible way: we could not weigh it, nor see it, nor receive sounds through it; could not feel it, should we strike our hands through it with our utmost force. Such a mere nothing is it. It is only when some very light body goes rushing through it, at the rate of thousands of miles an hour, that its presence becomes sensible in resisting somewhat the motion.

If we could visit mid-space, it would seem a perfect void, also dreadfully cold and dark and silent. The higher we go into our atmosphere, the colder it becomes. All mountain summits, above a few thousand feet, are covered with perpetual snow. Persons ascending in balloons at last reach a cold that is intolerable. They evidently approach the confines of an eternal winter, that, for silence and motionless fierceness, laughs

to scorn all that we have of arctic and antarctic.

According to the calculations of Sir John Herschel, we have only to go fifty miles from the earth's surface to reach — 132° Fahrenheit. Could we suddenly set down any moist thing at this point, it would instantly explode like a pistol, though without sound (for mid-space is soundless as well as matterless), and turn to stone as if touched by a magician's wand. And if, at this short distance from the earth and sun, space is so cold, what must it be in those remote vacancies where the sun shows as a mere star? In thought, we sail away most comfortably among the constellations, without furs or overcoat; and perhaps our fancies make nothing of stopping whole hours in mid-heaven, leaning against the chair of Cassiopeia, or grasping the horns of Taurus, to admire the glory of the trooping stars; but one real bodily expedition of the sort would forever cure us of such fancies. Perhaps of some others also; for, when our thoughts go yachting it through space, they are very apt to take with them, not only our genial parlor temperature, but also our pleasant earthly light and colors. But, in point of fact, the starry spaces are awfully dark. Those who visit the higher regions of our atmosphere, by mountains or balloons, tell us that the pleasant blue gradually passes into an intense black. At last, the stars glitter on a

background of perfect jet. To an observer out in mid-heaven, the whole sphere would seem muffled in a horrible pall, save just at the points where the heavenly bodies are. He would have the impression of not being able to see an inch before him. He would see sun, moon, and stars all at the same time; but they would look as if hissing on a sea of ink. The blackness would seem solid enough to be cut with a knife. An Egypt in the sky would seem to him to have completely overrun its Spain, and indeed its whole atlas of celestial empires. And should he try to express his feelings, and to say, "How awful is this blackness!" — "How glorious are these luminaries!" — no sound, nor specter of a sound, could issue from his shouting lips.

Such is the "House I live in" of the heavenly bodies. What are the heavenly bodies themselves — what this sun, this moon, these planets and comets and fixed stars and nebulæ?

In remotest times, very likely, men thought them distant heavenly torches, or openings of various sizes through the sky into an ocean of glory beyond. In process of time, they came to be very extensively regarded as intelligent beings — gods and goddesses, also human beings raised to the skies on account of illustrious merit, or, what was not always the same thing, the favor of the divinities. The sun was Apollo, god of fiery arrows; the moon was Diana, goddess of

the silver bow; and so on, until the sky was one great Parliament House of deities in everlasting session. Worship was paid to the shining crowd; to them incense rose, hymns were chanted, and victims bled. In civilized countries of modern times, people are far enough from such views of the nature of the heavenly bodies: multitudes do not even trouble themselves to have any views whatever on the subject. They have never put the question to themselves, "What are they — those bright lights above us?" Accustomed to the sight from infancy, busied in their digging and buying and selling, it has never occurred to them to be curious as to the nature of those far-off luminaries. They are content to have the use of them — to work by the sunlight, to walk by the moonlight, to steer, and perhaps to steal, by the starlight. In this respect, they are inferior to many in the remotest and rudest ages. And yet the question has long been well answered, and the answer is in possession of tens of thousands on all sides of them. What are the heavenly bodies! Not lamps, not apertures through which glory shines, not personages; but immense masses of unintelligent matter, some self-luminous, and the rest shining by reflected light. It is found that the light coming direcly from a candle, or other self-luminous object, differs by a certain property from the same light after it has undergone reflection. This fact enables us to

ascertain easily that a part of the objects in the sky shine by reflected light, while the rest are self-luminous. The sun, and fixed stars, and nebulæ are found to be self-luminous; the moon, planets, comets, and zodiacal light shine only by the light that comes from these. If a man is confronted by what purports to be a ghost, he pronounces it well-authenticated flesh and blood just as soon as he sees that it casts a shadow; so, just as soon as we find that the heavenly bodies emit and reflect light, we know that they are true matter; and, so far as we have been able to observe this matter, it has the appearance of that which composes our earth. If the moon is looked at through a telescope, we see a rugged surface of mountains and valleys. In regard to the other bodies in the sky, the glass does not serve us as well; but the telescopic aspect of most of the planets gives none the less decidedly the impression of an earth-like surface. But the heavenly bodies are not only masses of earthy matter: they are masses of immense size. They look small to us, it is true — the sun and moon occupying no larger space in your eye than does the crown of your hat at the distance of a few feet, and most of the stars showing as mere needle-points. They do look very small, most certainly; but so the great earth would if we should go very far away from it. The earth is so large that we can travel upon it for months

and years without crossing our track; and yet, should we go off into space from it, this immense bulk would gradually lessen on the eye till at last it would appear no larger than the smallest star. Though the dog bays at the moon as if it were within hearing, though the savage thinks that he could almost bring down the sun with his arrow, though so intelligent a person as Virgil tells us of a personage who brushed the stars with his sublime head, yet it is very easily discovered that the nearest of the heavenly bodies must be thousands and thousands of miles away. This is proved by the fact that only a few of them appear to change their places on the sky at all in consequence of any change, however great, in our position, and these few only in a very slight degree. A few steps will change the place on the heavens of some near objects a whole quadrant: but yonder mountain, twenty miles away on the horizon, would scarcely seem to stir should you walk an hour perpendicular to the line of its direction. Now, as to the heavenly bodies, it is found that one might travel thousands of miles on the earth, without shifting the apparent place of most of them on the vault in the slightest — without shifting the apparent place of any of them, save by a very trifling amount. So it is plain that they must be at a very great distance from us. Why, if a body were displaced on the sky to the amount of the moon's apparent diame-

ter, by our going a thousand miles on the earth, it must be a hundred thousand miles away; and there is not a body in the whole heaven that would undergo any thing like that displacement were we to remove such a distance. So we must conclude that all the heavenly bodies are immensely remote from us, and so of immense magnitude.

How are these great masses of matter actually disposed in space? According to some principle of orderly arrangement, we should presume. The Supreme Cause is no friend to confusion. Still, what the celestial order really is, is not easily discoverable. There is, to first view, no system whatever in the distribution of large portions of the heavenly bodies. It is as if the Genius of disorder had sown them. In other parts, there are appearances of systematic arrangement; but then the question arises, Is the apparent arrangement the real one? Can I say that two stars are actually near each other in space, because they appear near each other on the sky; or that other two stars are remote from each other, because one appears in the east, while the other is seen in the west? Not as long as I find, that, by putting myself between two trees only ten feet apart, I project them on directly opposite points of the heavens; not as long as I find that the tree which is only ten feet from me, falls on the sky at the same point with yonder mountain which is twenty miles away. So there was no small difficulty in ascertaining the real

plan among the celestial bodies; and, in fact, it was not ascertained till after long ages of observation and study. But persuaded, as thinking men were, that there must be system everywhere within the domains of the Supreme Wisdom; well aware, as most of them were, that apparent confusion, from unfavorable points of view, often covers a system of exactest order — they did not give over to inquire. At last they found the favorable stand-point which laid open the whole mystery of the celestial arrangements. The lamps of a city, as one approaches it some evening, appear a mere chaos of bright points; and yet that city is Philadelphia, where streets cut streets desperately at right angles and all the lights gleam on the sides of perfect squares. And they seem so to the same man, when, turned æronaut, his balloon has shot him up thousands of feet over the centre of the city. He has now found the true point of view. An army engaged in battle seems an inextricable maze to a looker-on from the same plain — men projected on and crossing men till all individual outlines are lost — and yet here are all the parts of a host, from corps to companies, each under its own leader, in unbroken array and admirable discipline, pressing forward on victory to the rhythm of exulting trumpet and drum as only Napoleon and Austerlitz know how to pour them along. And it seems so to the same man just as soon as, arrived at yonder lofty hill-top, he mingles

with the Emperor's staff and looks down on the whole scene. He has now the true point of view. So, at last, astronomers have found their true point of view. They look from over the beaming city. They gaze down on the rushing army. And now the whole celestial economy of arrangement stands unfolded. What is it? The system of arrangement is this: —

1. A body, not self-luminous, has one or more like bodies revolving around it. There are many such systems, which we will call *satellite-systems.*

2. Several of these primary systems form a still larger neighborhood, and revolve about a self-luminous body, like the sun. There are many such systems, which we will call *planet-systems.*

3. Several of these planet-systems form a still larger neighborhood, and revolve about a common point within it. There are many such systems, which we will call *sun-systems.*

4. Several of these sun-systems form a neighborhood still larger, and circulate about one point within it. There are many such systems, which we will call *group-systems.*

5. Several of these group-systems unite in a still larger neighborhood, and in revolving about a common point within it. There are many such systems, which we will call *cluster-systems.*

6. Several of these cluster-systems combine into another system still grander, whose centre of mo-

tion is also common to all its members. There are many such systems, which we will call *nebula-systems.*

7. Finally, all the systems of space, composing one great neighborhood that embraces all other neighborhoods, revolve around one motion-centre of the creation. This we will call the *universe-system.*

You see that it is a wheel within a wheel. Certainly, the 'height of that last, all-embracing wheel is exceeding dreadful.' Each order of systems includes all the orders below it; and each primary system has at least as many revolutions as there are different orders. It is very like the arrangement of human society. First, we have the elementary group of the family, revolving about the home; then several families, making a town, revolving about its central village; then several towns, making a county, revolving about its county seat; then several counties, making a State, revolving about its State capital; then several States, making a nation, revolving about the national metropolis; then several nations, making a world, revolving about the political centre of humanity, which once was Rome, which now is — shall we say London or Paris or St. Petersburg or Washington?

Take another illustration; for it is important to have this matter familiar. In these warlike times, it is hard to resist dealing in warlike illus-

trations: besides, it may fairly be presumed that they will be understood with special facility. Imagine the encampment of a great army. On entering it, the order in which the tents are disposed does not readily appear. But, on examination, we find that there is a very rigid system of arrangement, and that this is it, First, the camp of the company about its captain, separated by a plain interval from all other company-camps. Next, expanding around this, is the camp of a regiment about its colonel, separated by a still more marked interval from all other regiment-camps. Then, expanding around the regiment, is the camp of the brigade about its brigadier, separated by an interval still more decided from all other brigade-camps. Further, expanding around the brigade, is the camp of the division or corps about its major-general, separated by an interval still broader from all other corps-camps. Lastly, expanding around the corps, is the whole encampment of the grand army about its general or marshal or monarch. See here a picture of the great encampment of the sky! I say "encampment;" for, to one watching the sky for a short time, every thing seems stationary. But, really, the sky is not a camp. It is rather a glorious parade ground, full of motion, full of orderly, systematized motion — a flaming bannered field on which the various celestial powers are going through their various related evolutions

under their respective leaders — companies of stars manœuvering under star-captains; regiments, brigades, divisions, whole hosts of stars, manœuvering under star-chiefs of as many ascending grades of rank and splendor. Hail, host of heaven! Hail, glittering rank and file! Hail, gorgeous commanders in golden mail, and shining far o'er the field! Veterans all, though unscarred, as far as we can now see, — all hail! for, as we shall soon find, such brilliant equipment, such skillful commanding, such perfect obeying, such complicate wheeling on exactest time and admirable step, was never seen in any terrestrial army.

But you would like the evidence that such is the arrangement of the heavenly bodies. It is observed that every thing on the earth is heavy. We never take up any thing about the earth, whether great or small, whether this sort of matter or that, without finding it to have more or less weight. That is to say, the earth attracts it, or it attracts the earth, or, perhaps, both mutually attract. Newton, on thinking the matter over (we know how it happened, under the famous apple-tree, and how, as the apple came down, the thought of the philosopher went up), concluded to adopt the last view, and to suppose that an attractive force, developing itself equally in all directions, and extending to all distances, belongs to every atom of matter, terrestrial and celestial. On the

basis of this assumption, he was able to prove, mathematically, that every body must attract every other body with a force proportioned directly to its own quantity of matter, and inversely to the square of the distance between the bodies. If you double the amount of matter in a body, you double its attractive force; if you double its distance from another body, you quarter its attractive force on that body. With this law, he proceeded to demonstrate, by the most rigorous of mathematics, that, if two or more free bodies in space form a neighborhood, they must instantly rush together, or they must all revolve about their common centre of gravity; meaning, by this common centre, that point among them where their several attractions just balance each other, so that a particle at that point would have no tendency to move. The fact that such bodies are found apart, after an existence of thousands of years, will then be proof that they are all revolving about their common centre of gravity. Hence, if several celestial bodies are found contiguous, as compared with others, we must infer that they form a system of revolution by themselves; if several of these minor systems are found contiguous, as compared with others, we must infer that they compose a still larger revolving system; and so on. Or, if we find certain heavenly bodies forming together a system of revolution, we must infer their relative contiguity

to each other in space. We need only to establish, by observation, the actual existence of either such celestial neighborhoods as have been described, or such related motions as have been described, in order to establish the existence of both. Now we can always do the one or the other.

But one suggests, "There is an assumption at the bottom of this argument. Newton assumed that attractive power, flowing out equally in all directions and at all distances, belongs to every particle of matter, celestial as well as terrestrial. Where is the proof that this assumption is correct?" I answer, that we have no other proof than is involved in the fact, that, after very long trial, the results flowing from the assumption have not been contradicted by any known fact, while they wonderfully harmonize with and explain all the leading astronomical phenomena. A man computes, by the law of gravity, just where in the sky a planet or comet ought to be found at a given time; and, when the moment comes, we look at the spot, and lo! the body is there. Feats of this kind have been so numerous; the law of gravity has been tried for the explanation of such hosts of astronomical facts, and with such invariable and brilliant success — that astronomers have at last come to rely on its truth with unbounded confidence. And they are philosophically obliged to do so. The original assumption stands proved

by an overwhelming experience. It has been gradually established by an immense induction of particulars. And now men can not refuse confidence to it without rejecting that Baconian philosophy which lies at the foundation of all our modern science.

That you may still better realize the weight of this proof, let us suppose a case. Imagine an immense castle, with every gate and door about it locked. You are informed, on authority that you can not question, that there once existed a single key which could open every room and closet and drawer of the edifice; but, alas! it has long been lost. One day, in walking about the premises, you stumble on something that looks very much like a key, an ancient key, a key that on pressure of a spring can be made to take almost any shape. Well, you can not help your thoughts: they do at once suggest to you that, perhaps, you have been fortunate enough to fall in with the long-lost wonderful bit of iron that can let you into every part of the sealed castle. Still you could be surer — a great deal surer; in fact, you have very serious fears lest, on trial, your key shall prove a mere pretender. Tremblingly you try it on the court-yard gate: after some trouble, the gate flies open. Your courage rises. Eagerly you approach the main entrance, and try that: after a while, that too gives way, and you enter the castle proper. You are now still more sanguine that your key is

the true one. Still, it may fail at the very next trial. So you proceed to question another door, and another, and still another; with continually augmenting confidence as success follows success. You find very great difficulty at times, both in adapting and turning the key; you have to delay before some doors a long time; but, in nearly every case, success comes at last. And now, on counting up, you find that your key has opened for you all the main rooms in the castle; in fact, all that you have seriously and patiently tried — doors of oak, doors of iron, doors with locks of the strangest and most intricate pattern — it has conquered them all. At length you are perfectly satisfied. You would not give the snap of your finger for any additional evidence that your key is the genuine. Should some one come to you and say, "My dear sir, are you not a little too credulous — do you not give your faith in this case a little too easily — as for me, I am not quite sure that there is no mistake, am afraid you have not the true key yet!" — you would be tempted to reply, "My very wise sir, when did you escape from the asylum?" Such a man is beyond argument.

Now, this is just the case that has been presented to astronomers. Here is the immense sky-castle, that, from the beginning, has been fast locked up from men — a huge, inaccessible, inhospitable warrior-monastery. Men knew there must

be some clew to those mysterious cloisters — some key or keys that could match the wards of those innumerable locks. Where was it? None knew. It had never been seen from the beginning. Did the architect, as soon as the magnificent structure was finished and carefully locked up, like the God of the "Night Thoughts," fling the key from the starred battlements far into the pitchy and bottomless abyss of space? But no, this could not be; and so men went to roaming about the purlieus of the heavens, looking for that lost Pleiad of a key; and oh, how often, meanwhile, did they throw longing, not to say despairing, glances at that stern, unrelaxing sky where such treasures of science were keeping eternal quarantine! At last Newton, one of these seekers, stumbled on the law of gravity. Is this the key? It has the look of one; for it is seen at once to harmonize and explain many terrestrial facts. It looks like a multiple key; for it is wonderful what a variety of great theorems may be drawn out of this same law of gravity. As it were, you have but to press a spring to make it assume an almost endless variety of forms. So Newton's heart fluttered with hope — mere hope. Tremblingly he put his key to the test. What was his joy to hear that first ponderous bolt fall back? Success followed success; courage swelled on courage. Newton himself lived long enough to unlock several of the main gates of the heavens

with his own hands. Encouraged by his success, many other strong and skillful hands grasped the victorious law of gravity and essayed other entrances,—sometimes succeeding easily, and sometimes with no small difficulty and delay, but nearly always succeeding. So it has gone on up to the present time — door after door opening — doors of oak, doors of iron, doors of brass, doors of gold, doors of the strongest look and lock-pattern, doors by scores and hundreds — they have gone on yielding, one after another, to the wondrous key, till now we may speak of the Open Heavens. "What, Earth and Moon open! Have you unlocked their hundred-gated theory?" Yes: not a considerable gate of that Thebes but has described a complete semi-circle. "What, Sun and Planets open! Has your key of gravity set their thousand gates a swinging?" Yes, swinging to their full capacity — thanks to the dexterous and patient handling of wedded observation and geometry. "What, Star Groups open! They have a myriad of strange and ponderous gates; and have even these yielded?" Ask the Herschels and Souths and Bessels. Yes: even those wards are not too intricate to be traversed by the victorious tenons and tongues of the law of gravity; and now, if you choose, you can step over the golden threshold of many a planetary sun, and see for yourselves the marvels within. "What, Clusters open! What Nebulæ open! And now I say, Hail to the law of grav-

ity, if it can fling open to the gazing science of men those million-gated and doubly-locked regions! Can it, indeed, do that topmost feat?" Ask the Struves and Peters and Argelanders and Mædlers; and have not we ourselves heard, with our own ears, the recoil-thunder of some bolts under the strong hands of these giants? Yes: I have myself seen some of those burnished gates shot back to the very wall, and the philosophers who accomplished the feat yet standing, key in hand, with flushed faces, gazing into the audience chamber and royal pavilions of that highest heaven of matter. God bless the key! It is GENUINE.

III.

SATELLITE SYSTEMS.

III. Satellite Systems.

Example—Earth and Moon.

THIRD LECTURE.

SATELLITE SYSTEMS.

IN the last lecture I stated how the Heavenly Bodies are arranged in space. They are distributed into neighborhood systems of at least seven orders. These are the Satellite Systems, the Planet Systems, the Sun Systems, the Group Systems, the Cluster Systems, the Nebula Systems, the Universe System. Each order of systems includes all the orders below it; and the members of each system revolve about its center of gravity. I will now proceed to prove and interpret these systems in the order named.

A Satellite System consists of two or more contiguous heavenly bodies which are not self-luminous, and which revolve about their common center of gravity. There are many such systems; but the most accessible and useful example which I am able to present is that of the earth and moon.

It was long before men were prepared to reckon the earth among the heavenly bodies. It seemed at first view so different from them — so unshin-

ing, so like an indefinitely extended plain with solid foundations of endless depth. But further thought corrected this mistake. Whence come the sun and stars as they rise in the east, and whither go they as they set in the west? It is clear that they pass, on the average, twelve hours out of the twenty-four under the earth. So the earth is really a body of finite though great extent, lying loose in space — space under it, space over it, space all around it. Of course it must be so. As to the notion that the earth does not shine like the distant heavenly bodies, it is quite without foundation. Our world does not appear as brilliant, simply because we do not see it from out of the midst of the night as we do the moon and stars. They do not appear bright by day — for the most part do not appear at all — it is only when they are in the light while we are in the dark, that they seem to us to shine. If, some evening, when your room is brilliantly lighted, you take your stand in the middle of it and try to look out into the street, you can see nothing; but persons passing can see you and all your movements. To them you shine. And could we take ourselves away into that pitchy space that expands around us, till the earth should appear no larger than the moon, it would appear as bright as that luminary.

The earth shines like a star. It shines, however, only by reflection. Just as soon as the

light of the other heavenly bodies is shut off from any part of its surface that part becomes dark. In this respect the moon is like it. We notice that it is only that side of the moon that is toward the sun that is bright; and so it happens that for the greater part of the time the great light that rules the night appears to us under a broken circle. Also, the fact already referred to, viz., that reflected light has a different property from that which comes to us directly, enables us to pronounce the moon a mere reflector. So neither the earth nor moon is self-luminous. They fulfill the first condition of a satellite system.

Do they fulfill the second condition? Are they contiguous to each other as compared with other heavenly bodies? If so, the law of gravity proves that they both revolve about their common center of gravity. Now this matter of neighborhood is easily settled. Ask whether any other heavenly body shifts its place on the sky any thing like as much as the moon, in consequence of a given change in our place. By going four thousand miles on the earth we change the moon's place by about twice its apparent diameter. No other body in the heavens experiences the hundredth part of this change. The earth and moon, therefore, form a neighborhood. Hence they must revolve about their center of gravity. And being both heavenly bodies, shining by reflected light, they make a satellite system.

Now let us notice the chief facts which have been ascertained concerning this primary system. And, first, each member is found to turn around on itself. What makes the stars rise in the east, move uniformly across the sky in parallel lines without disturbance of their mutual positions, set in the west, and, at the end of twenty-four hours, appear in the east again? The most simple explanation is that the earth turns around on one of its diameters from west to east, with a uniform motion, once in twenty-four hours, while we are held to its surface by the attraction of gravitation. Indeed no other explanation is admissible. The idea that we are the center of creation, and that all the host of heaven, at as many different and immense distances, have their motions so adjusted to each other as to make the circuit of the earth in exactly the same time, is altogether too cumbrous to suit either philosophers or practical men. Besides, such a system is irreconcilable with the law of gravity. If it is in the nature of things possible that the earth is the center of the universe, it is not possible that all the heavenly bodies should so fly in the face of gravity as to revolve about this center — or rather an axis passing through it — in parallel circles, in precisely the same time or in any times. So we are bound to conclude that the earth moves about an axis within itself, and thus gives us the beneficent alternation of day and night.

But why are we not sensible of this motion? How is it possible that we can be whirled around so fast as the rotation of so large a body implies, and be a good part of the time, as people say, standing on our heads, and yet remain entirely uninformed by our senses of what is going on? Why, every thing about us shares our motion; even the atmosphere goes around as fast as we do; there is no jolt nor jar — how should we know, except by seeing objects moving by us, that we are in motion, any more than does the man engaged in the fairest summer sailing? Were he to shut his eyes, there is nothing in his sensations to show him that he is gliding along: were he to open them only on the yacht and its furnishings he would seem at rest: he must look away to the shore, and see the trees and houses slipping by. So we are rolled around the world so smoothly and equably that we have to look away to the stars to know that we are rolling at all. Noiselessly, without hitches, without tremors — it is the perfection of lubricated and luxurious progress! The softest, downiest, springiest chariot that ever went rolling over its McAdam, with a prince inside, is an earthquake compared with this natural omnibus in which we have taken passage. As to the prejudice which some persons feel against having their heads point in diametrically opposite directions at different hours of the day, I do not know what can be done for their

relief, unless it be to assure them that they shall have the privilege, during their daily somersaults, of always pressing their feet against the ground and holding their heads aloft in the air.

A single evening's watching of the stars is enough to show us that the axis of the earth points nearly at the North Star; that the motion around it is easterly; that it is a perfectly uniform motion, just the same distance being made in the same time. So much a single evening can show us. But it would take a great many evenings to show us another striking fact, none the less sure, viz., that the axial revolution is always accomplished in exactly the same time. It is on evidence that our day has not varied the hundredth part of a second for two thousand years. There has not been the slightest change within the long sweep of history and tradition. We must, however, allow one or two exceptions. "Sun stand thou still on Gibeon, and thou Moon in the valley of Ajalon! So the sun stood still in the midst of heaven, and hasted not to go down about a whole day." The Chinese have a tradition that there was once a day of double the usual length. And the Greeks have a fable that may refer to the same thing — that the son of the Sun once persuaded his father to allow him to drive his fiery chariot for a day. The result was that such another Phaetonizing never took place. The met-

tlesome steeds ran away with the youth; wandered up and down the sky, setting every thing in a blaze; and did not reach the gates of the west — how could they — till a long time after they were due. So there has been a day of extraordinary length. The Bible-miracle, however, may have consisted, not in suspending the motion of the earth on its axis, but in simply bending the rays of light from the sun and moon so as to continue the illumination, apparently from the same points of the sky, long after the bodies themselves had passed at their usual pace below the horizon. Certainly, one or two miracles aside, the length of our day has never changed by the breadth of a hair: the earth wheels about on its axis now in just the same period as at the creation. So we have a beautiful unit of time to carry along with us in our terrestrial journeys, though altogether too small for journeys astronomical.

On looking at the moon, to find whether it also turns around on itself, first appearances are against it. Bring a telescope to bear on its face. We can see many striking objects, but no considerable movement among them. In case of a rotation we ought to see all such objects moving across the disc in parallel lines. But, instead of this, we find them substantially stationary. Strange to say, this very fact, which at first view seems conclusive against a rotation, is the very

fact which establishes it. For, on second thought, you perceive that in case the moon does not turn on itself, whether we move around it or it moves around us, we ought in the course of a revolution to see it on different sides. The fact that we see but one side can only be accounted for by supposing that the body turns around on one of its own diameters, just as fast as the other revolution is made, in the same direction and nearly in the same plane. We shall soon see that this revolution consumes about twenty-seven days. This, then, is the time in which the moon turns completely around on its axis. This is the moon's day. Its day and month are of the same length.

I have said that the moon is greatly more displaced on the sky by a change in our place on the earth than is any other heavenly body. Hence I inferred that it must be greatly nearer to us. But that is not saying that it is very near; indeed, it is not saying but that it is a matter of some millions of miles away. The fact is, that, though a neighbor, the moon is a very remote neighbor; at least, according to such standards of distance as we use in our every-day affairs. But we must hasten to enlarge our common units both of space and time. Astronomical systems, we shall find, are laid out on a different scale from the neighborhoods of this world; and miles and days make but a sorry figure in attempting to deal with the smallest of the mighty parishes

of the sky. The moon is 240,000 miles away. And this is a very close astronomical neighborhood; though hardly close enough to enable us to act the part of the good Samaritan to our neighbor, in case it should fall among thieves; though hardly putting it within visiting distance, except for our thoughts, which have both the taste and the faculty for riding on beams of light and the Pegasus of poets. I say 240,000 miles, on the average, and in round numbers. One French astronomer, La Lande, goes to Berlin, in Prussia; another, La Caille, goes to the Cape of Good Hope. One marks where he projects the moon on the sky at a given moment; the other where he projects it at the same. They compare notes. Difference between the two projections found to be so many minutes and seconds. How far apart are the two stations? So many degrees of latitude, and so many miles in a straight line. Nothing more necessary than to sit down, and by a simple calculation in triangles which any child well advanced in his arithmetic can perform, find the distance of the moon from the earth's center. The exact mean distance is found to be 238,545 miles.

Now let us turn our attention to the shapes and sizes of the members of this satellite system. And, first, each member has been found to be a round body, slightly flattened on two opposite sides. A rubber ball slightly compressed between

your two palms will represent the figure. How round the sky looks! Whoever has been at sea has noticed that the topmasts of ships are seen first, from whatever quarter they may come. Look at the drops of rain; the beads of dew with which the spider-thread is strung, or which start from the brows of labor and terror; the round shot, which, when a moment ago they left the top of the shot-tower, were one irregular mass of molten metal. Newton has proved mathematically, that the particles of a body, if free to move under the influence of gravity, must always arrange themselves in a globular shape. Now geologists tell us that the particles which compose the earth were once in this free state; that far back, before man's day, the entire solid, rocky world was in a state of fusion. We should therefore expect to find it of a rounded figure. More than this. The earth revolves on an axis. The necessary effect of this rotation on a fluid mass would be to draw it in at the extremities of the axis — the poles so called; and puff it out midway between these points — that is to say, at the equator. But we are not left to this reasoning. Have not men sailed around the world by sailing always in one general direction, and without being sensible of any abrupt change of level? It has been proved that the attraction of a round body on objects external to it is as if all its atoms were concentrated into one at its center. This

being so, if one would be nearer the center of the earth when at its pole than when at its equator, bodies ought to fall more rapidly as we pass from the one toward the other. They are found to do so. A pendulum descends with increasing speed as we increase our latitude; and it has been found that the rate of increase in the motion is such that the pole must be nearer the center of the earth than the equator is, by a six-hundredth of an equatorial diameter.

Now the moon is just another such body — rounded, but not a perfect globe. At the full, its disc appears as a complete circle; and its apparent shape at other times — as crescent, half-moon, gibbous — can only be accounted for on the supposition that it exposes a globular surface to the rays of the sun. And, as it revolves about one of its own diameters, we conclude from analogy as well as from the demonstrated tendency of the atoms of all rotating bodies, that it is slightly flattened at the poles.

Almost every one has himself moved about on the earth enough to satisfy him that it is a very large body. The man who has sailed around it, and at the end of his two or three years of voyage finds himself where he started, does not need to consult his log-book to know that its circumference must be some thousands of miles. But this knowledge is far too vague. So we will make a still further approximation. Find a level

region, and then measure due north or south on it till you have changed your latitude one degree. This measure multiplied by three hundred and sixty gives you the true circumference of the earth, supposing that circumference to be strictly circular. The result is about twenty-five thousand miles. This is a close approximation; for, after all, the earth differs but very little from a perfect sphere. Still astronomers are not content. They know the body is not an exact sphere. They have a sort of constitutional weakness for the last degree of accuracy — they must hunt down, if possible, the ten-thousandth part of a mile in favor of both equatorial and polar diameter. And, indeed, it was a matter of such great practical consequence to know these elements with minute precision that Governments stepped in with their vast resources to help measure them. Coalitions in behalf of the balance of power became, for the time, coalitions in behalf of astronomy. For the time, jealous and hostile powers resolved themselves into a Committee of the Whole on the diameter of the earth. Nations took stock in degrees of latitude as people lately did in petroleum. "Select your men and instruments," said some six or eight Governments to men of science, "and we will pay expenses." So the work was put into choicest hands; the choicest instruments were gathered; and the illustrious laborers bent themselves to their task with the

determination to spare neither time, nor pains, nor expense, to secure the most reliable results. Their object was the same as in the case just supposed. It was to measure lines running due north or south on the earth — only they would measure very long lines, very many of them, and in as widely differing latitudes as possible. Thus they would get a choice average length of a degree of latitude, and also settle with great precision its rate of increase as we go from the equator toward the poles. But it is hard to find level districts of great length on due north and south lines. So they determined to follow the level regions in whatever direction they ran, and indeed, on occasion, forsake them altogether; and afterward reduce their zigzag measurements to the meridian and sea-level, by means of triangles and levels. And so they did. They wove a network of triangles across large tracts of country in various parts of the world. They went stooping along the dead plains, chain in hand, for their base lines; they went spying from hill-top to hill-top, and from beacon to beacon, with their theodolites and circles — as our own Coast Survey Commission were seen doing in this neighborhood some years ago, and as they have been doing on other parts of our mighty coast as fast as the mighty war would suffer them. International triangles united countries as international railroads do now. Let France hold up this angle,

Spain that, Italy the other! No climate was too hot, none too cold, for these zealous workers. Trigonometries could stand any climate — why should not Clairaut and Godin? So forward, ye pilgrim geometers! Spread out your triangles along the plains! Hang them from the tops of mountains! Float them along the seas! Stretch them across the sands of the desert! Shadow them with jungles and palms, and blister them with vertical suns! Anchor them to icebergs, and bury them in eternal snows! And so they hardily and audaciously did. A line of 16° of latitude was measured in India, of 12° in France, of 4° in England, of 3° in Russia, of 3° in Peru, of 2° in Italy, of 1° each in Sweden, Lapland, Africa, United States — indeed, twenty independent measurements in all. The results obtained from a combination of these were 7,925.648 miles for the equatorial diameter, and 7,899.170 for the polar.

The old magicians drew circles; these new magicians drew triangles. The former were supposed to get wondrous results out of their figures, drawn with many a muttered hard word and strange gesture — what will these philosophers get with their words as hard, and pointings as mysterious, and figures as uncouth? Nothing, my friend, nothing but the diameter of the earth in good British statute miles and thousandths of a mile — which, however, happens to be worth more than all the work done by all the magicians,

astrologers, and soothsayers, from the days of Berosus downward.

The moon can not boast such great dimensions as the earth. Still it is wonderfully larger than it looks. It looks, say, a foot in diameter; it really is eleven million times that. It is plain that can not be a small body which, on being carried away from us 240,000 miles, appears as large as the moon. But this is altogether too vague information to content astronomers — astronomers who want to split a second into one thousand parts, and an inch into 200,000. "What is the exact length of the diameter in miles and smallest possible fractions of a mile?" demand they. And they answer themselves in this way. Suppose two lines drawn from the earth's center to opposite sides of the moon; then the real diameter of the moon makes with these a triangle. Now measure the moon's apparent diameter, which is the angle included between the supposed lines. The lines are about 240,000 miles each; the angle is about 31′. Then the simplest sort of mathematics gives you two thousand one hundred and sixty miles for the required diameter.

Though the moon is so small a body compared with the earth, and withal so remote from us, it is able to produce on us some very remarkable effects. Most certainly I do not here refer to its supposed bearing on the weather, on the complexion, on

the health, on the mind in producing or modifying insanity, on the proper times for planting, reaping, felling timber, killing of domestic animals. Though the impression was once almost universal, and is still exceedingly prevalent, that the moon is a powerful and controlling agent in these and such particulars, still we must admit that it is an altogether erroneous impression. This has been very satisfactorily established by the extended observations and experiments of several European philosophers, and especially of the illustrious Arago. No: I refer to quite a different class of phenomena. And, first, the moon takes hold of that protuberant equator of ours, as if it were a mere convenience for wrestling, and pulls and twists it about after itself, making the pole describe a wavy, nodding circle of some 46° diameter through the sky — a little more than the hight of the North Star above our horizon. This effect is due partly to the sun; but the moon is the chief agent. For long periods, however, this motion of the pole would not be noticed by common observers; it is so exceedingly slow, requiring about twenty-six thousand years to make an entire revolution. In consequence of it, the axis of the earth which now points nearly at the North Star, will, after pointing a little nearer to it, gradually recede, and twelve thousand years hence point 40° away from it; and then the bright star Lyra will be the pole-star.

Let the men of the year 13,860 look in the north-west for their north.

Another more noticeable effect of the moon's attraction are the tides. Twice a day the earth, like every good man, attempts communion with the sky. Twice a day the bosom of the seas swells heavenward. The explanation is this. As the earth, in revolving on its axis, presents all parts of its surface in succession to the moon, that body, by the attraction of gravitation, draws up the water in a ridge toward itself, at the same time making a similar ridge by drawing the earth away from the water on the opposite side: so that we have two great tidal swells, convex toward the west, about twelve hours apart, apparently following the moon in its daily movement around the earth; checked somewhat in their movement by their own inertia and friction among the barriers of shores and irregularities of sea-beds; reflected in this direction and that, according to the lay and shape of coasts; about two and a half feet high on the average, but heaped up as high as fifty or even one hundred and twenty feet in some confined places of peculiar conformation, and then almost or quite dissipated by shoals and other dispersive agencies. Thus it would seem to a bird's-eye view. But really there is no progressive movement of the water in the open sea in the case of the tides. No European water is rolled over to America at the rate of a thou-

sand miles an hour. It is merely a successive rising and sinking of the sea all round the world. The effect is owing in part to the attraction of the sun; but the moon is the chief agent. When the sun and moon act in the same line, or nearly so, — at the times of new and full moon — the tide-swell is considerably increased, making what are called spring tides. When they act at right angles to each other, they impair each other's influence and the tide-swell is decreased, making what are called neap tides.

This constant heaving of the water tends to keep it pure. It also agitates to some extent the atmosphere, and so keeps that in a livelier and purer state. It enables all the coasts of the world to become vast beds of a peculiar animal and vegetable life, and twice a day throws open the repositories to the plundering hands of men. The farmer wants his sea-weed and salt grass. All persons, almost, want their shell-fish. Millions of people find their chief support in those vast tribes of animals that can only live where tides are felt. Shoals are laid bare and quickened by the sun. The tide-wave brings up the water again with its flotilla of semi-marine animals and influences to impregnate and refresh the congenial sand or slime. So the beach swarms. Races of creatures belonging to both land and sea, and partaking of the qualities of both, present themselves for our tables in countless numbers — not

by spontaneous generation, that figment of atheists, but by the good providence and almighty power of God.

How much matter is contained in the earth? What is its average degree of compactness? In the year 1774 — the same year we Americans were weighing the maternity of England in the balance and finding it wanting — England attempted to weigh the world. For that purpose, the astronomer royal, Dr. Maskelyne, betook himself to Schehallien, in Scotland. He suspended a plumb-line near the mountain, and noticed how much it was drawn out of the perpendicular. This showed what proportion the quantity of matter in the mountain bore to that in the earth. Then cuts into the mountain in every direction were made to show the average density of the materials of which it was composed. With this, the size of the earth being known, it was very easy to arrive at its average density — which was found to be about five and a half times that of water. This greatly exceeds the density of the surface. So there must be a great increase of condensation toward the center. It does not follow, however, that the earth is perfectly solid, — the contrary is known — only the parts that are solid must be exceedingly so; fit walls against those tremendous internal fires that help the sun defend us from the tremendous cold of space; fit walls against the noxious gases and vapor

which those fires can not fail to generate in prodigious amount! For the earth is like some men — with a cold exterior, but a heart of fire. It is a traveling furnace. Wherever we dig into it, we find a steady increase of heat — one degree for each fifty-four feet as we descend. And you know how unlike are the climates of different countries having the same latitude and level — for example, Southern Europe and New England and the States due west of us. When the ancients saw Ætna in eruption, they supposed the mountain to be the chimney to the great blazing and resounding forges below, where Vulcan the god-blacksmith, with his journeymen-Cyclops, were hammering out the thunderbolts of Jupiter. When we see Ætna and its three hundred sister volcanoes, in all parts of the world, in action, we make no question but that the immense roaring fires are beneath them, if not the forger and the smiths and the thunderbolts. That the great amount of vapor and gases which must be developed by these fire-beds does not all escape through fissures and volcanoes as fast as formed, is plain; for the many violent and far-spreading earthquakes that occur, come from the struggles of imprisoned elements to escape. They are densely accumulated in great caverns. And it is well that the walls of these caverns are denser than the densest metals known to us, so that but comparatively little of the deadly air within

succeeds in escaping to the surface. Indeed, so little heat escapes that the earth has not diminished its mean temperature by the three-hundredth part of a degree for two thousand years.

Can we also weigh the moon in our astronomical balance? We can; by means of the tides. Add together the average spring and neap tides — the one expressing the sum, and the other the difference, of the solar and lunar attractions. This gives us that part of the tide-wave which is due to the moon alone. Now how does this show the quantity of matter in the moon? You see it is a case of contest between the earth and moon as to which shall have the water. The earth pulls with all its might — that is to say, with all its quantity of matter; and the moon pulls with all its might — that is, with all its quantity of matter. The moon acts at disadvantage from its greater distance, the earth acts at disadvantage from the tendency to fly off which the water has in consequence of rotation; but, when allowance is made for these things, the position which the water takes between the two pulling bodies shows their relative strength. It is the case of Greece and Troy dragging at the body of Patroclus. The one tugs at the head, and the other at the feet; the direction in which the body actually goes shows which party is the stronger, and the rate at which it goes shows how great the superiority is. At last the dead hero moves swiftly

toward the ships. Not eighty wrestli..g Troys could prevent it. In this duel for the seas, we are Telamonian Ajax, and the will of Jupiter besides; and it would require more than eighty moons to turn the fortunes of the day, and tear its prize from the stalwart earth. Just as soon as we know the relative quantity of matter in the moon, its known size shows what is its relative density. It is about three-fifths of the density of the earth.

It has been shown that the earth and moon, making as they do a neighborhood by themselves, must revolve about their center of gravity. Now, since the earth contains eighty times as much matter as the moon, this center must lie eighty times nearer to the center of the earth than to that of the moon. But the eightieth part of two hundred and forty thousand miles is three thousand. So you see that the point around which the two bodies revolve falls one thousand miles within the earth's surface — our semi-diameter being near four thousand. Hence it is comparatively but a very small orbit that the earth describes — only six thousand miles across; while the moon describes one which is four hundred and eighty thousand miles across. One is as nothing to the other. So, for popular purposes, it is common to consider the earth as stationary, so far as the moon is concerned, with the moon revolving around it. Turning, then, to this greater orbit,

I will state some of the more interesting facts about it. Plainly, it can not differ much from a circular curve; for the moon always looks just about so large during its revolution around us. If its distance from us varies considerably, of course its apparent size ought also to vary considerably. Very nice measurements, however, of its apparent diameter at different times, show that its distance does alter somewhat — more than it ought on account of our being a little out of its center of motion; shows in fact that the orbit must be what is called an ellipse — such a figure as a flexible hoop would make if compressed at opposite sides — having the common center of gravity about twelve thousand miles one side of its center, on the longer axis. It takes a little more than twenty-seven days for the moon to make the complete circuit of this orbit. This is traveling at the rate of fifty-four thousand miles a day. In passing around this orbit, our satellite often passes, either wholly or partially, through the earth's shadow; giving rise to lunar eclipses. As to the position of the orbit, we notice that the moon does not move around our axis at right angles to it, but obliquely; so that the plane of the orbit makes an angle of about sixty degrees, with the axis. This inclination is of great service to us; for it is owing to this that we have so much more light from the moon in winter than in summer; it causing the full moon to ride

highest when we need the most light. Here, then, we have the orbit — four hundred and eighty thousand miles the longest way across, lying obliquely across the axis of the earth, and traversed at a pace of fifty-four thousand miles a day. This is how the matter stands now. But you are not to suppose that it has always been so, or that it will always be so. The orbit is continually becoming smaller; the moon with every revolution is getting nearer and going faster; and some persons have been afraid that, at last, our neighbor would become too neighborly — in fact, come rushing in upon us, and with one tremendous concussion dash every thing to pieces. The fact of the gradual approach of the moon to us is certain; observations establish it beyond question. But it is an exceedingly slow approach, only ten seconds on the time of revolution being now gained in a century. Still, however safe we and many generations after us may be, the idea of such an ending of an astronomical system is not pleasant. We pity that distant generation to come. We pity the graves of our fathers and our own. However, we need not be alarmed. La Place, with his splendid geometry, has shown from the doctrine of gravity that this gradual contraction of the orbit is not to continue indefinitely; but that, after millions of years, it will again slowly expand and finally become as large as ever; then contract again — and so sweep back-

ward and forward through a period the vastness of which bewilders the imagination. This change in the lunar orbit is by no means the only one. There are some sixty such changes; and about half that number are so considerable that they must be taken account of, whenever we wish to compute the place of the moon with tolerable exactness. Indeed, the moon's orbit is a very wavy, changeable, battered affair. It is continually being pushed out and in, twisted in this direction and in that, drawn sidewise and edgewise, revolved in its own plane and in almost every other by attractions from many quarters. Could you see the path which our satellite actually describes in space — could it leave a visible wake as a rocket does — you would wonder greatly at its intricacy, and how men could ever get able to predict the moon's place on it to within five seconds of the truth. Yet this they can do. And astronomers have found out, by means of the law of gravity and that wonderful differential and integral calculus which is the good Genius of astronomy, that, notwithstanding the sad usage which the lunar orbit gets from all quarters, it has, like much assailed christian goodness, within and around it all the elements of eternal stability.

I will close my account of our satellite system by a few words as to the appearance which its members present to each other.

The appearance of the moon under the telescope is very beautiful. And yet it looks very much as if it had had the small-pox in the natural way, and had it sadly. We see a desperately pitted and scarred face — valleys and mountains — valleys four miles deep; mountains five miles high; volcanoes, conical, ring-shaped, with long streams of lava spreading down their sides in every direction; peaks gleaming with the first kiss of the morning sun; shadows advancing across the plains. As to atmosphere and water on the moon, appearances are indecisive. Some things seem to prove their presence, and other things seem as strongly to prove their absence. Certainly the moon has never any clouds. However, if it could be demonstrated that it has neither air nor water, it would not follow that it has no inhabitants. It would only follow that, if there are living beings there, they must be differently constituted from ourselves. And who will undertake to show that beings widely diverse from us are impossible or improbable in the universe of so versatile and magnificent a Creator as He who spake into being these wonderful worlds of astronomy?

This is how the moon looks from the earth. And how does the earth look from the moon, if there are people there to see? Half of the moon never sees us at all. To the other half we seem a brilliant orb about thirteen times larger than the

moon seems to us — always occupying nearly the same place in the sky — successively crescent, gibbous, and full — in fact, another moon. Under a telescope, what with our clouds and seas and valleys and mountains, the earth would present even a more pocked aspect than the moon does to us. Never did veteran come home from the war with half so scarred and battered a countenance! But never mind, ancient earth! Thou hast a better look on closer acquaintance. And, besides, "handsome is that handsome does," and thou generously givest us flowers and fruits and harvests and coal and silver and gold and gems; green fields, stately forests, musical streams; sweet vales of Tempe, hoary Alps sublime, august oceans with their eternal anthems; above all, a standing place on which Holy Christ and sinful we may work out for ourselves the wonders of eternal life.

IV.

PLANET SYSTEMS.

IV. Planet Systems.

Example — Solar System.

FOURTH LECTURE.

PLANET SYSTEMS.

IN my last lecture I gave an example of the First Order of Systems among the heavenly bodies — the Satellite Systems. This evening I propose to give an example of the Second Order — the Planet Systems, or systems each of which is composed wholly or in part of Satellite Systems revolving about a self-luminous body or sun.

The rotation of the earth makes all the heavenly bodies seem to move across the sky in parallel lines, without any disturbance of their mutual positions. But some of these bodies have very much motion of another kind — a motion among themselves. They go this way, and they go that; they go forward, and they go backward — describing quite rapidly very irregular paths on the sky. I have already called your attention to these very roving bodies, under the names of planets and comets. About ninety planets, and some one hundred and eighty comets, have been carefully noticed.

Some of these change their places among the other stars, on the average, as much as eight times the apparent diameter of the sun in a single day — indeed some comets have been known to traverse, in the same time, eighty times this diameter. Besides these, the sun itself is found to be a great traveler, though never a retrograde one — making the whole circuit of the heavens in a year. Now, the thing to be particularly noted, is the great difference in amount between the apparent motions of these bodies and the apparent motions of all others. Why, all others have no motions at all, that ordinary observers can detect, and hence are called fixed stars. And when astronomers mount their instruments, and do succeed in detecting small annual changes of place among them, they find that the greatest of these changes is a thousand times less than that of the slowest planet. Now what makes this great chasm? Why do these three hundred bodies seem to move so much, while all the rest seem to move so little? There is but one answer. Those greatly moving bodies are greatly nearer to us than are the others. There is a great interval between the two classes of bodies in space, corresponding to the interval between them in motion. If there were no space-chasm between them, the law of gravity would require them all to belong to the same system of revolution; of course, the real motions, and so the apparent, of all would be of the same general order of magnitude. Suppose

yourselves at sea in a fleet. Here are three hundred ships within two miles of you. Some are standing this way and some that, some advancing and some retrograding; but all noticeably changing their positions with respect to you and each other every minute. Now let another fleet appear on the horizon. You count a thousand tiny masts. Their progress seems as petty as their size, hours scarcely showing any change of position. What say you? That those Liliput ships with their Liliput motions are mingled with your own squadron, because, forsooth, you happen to see them between the neighboring hulls and masts? Not so. If they belonged to you, they would take signals from your flag-ship, and all the exuberant shipping in sight would have a family likeness as to the character and degree of their sailing. But here is quite another order of motions. They plainly belong to another fleet, under another admiral, far away in the offing; and distance has dwarfed both figure and motion. A great breadth of sea lies between the two navies. We reason in the same way in regard to the heavenly bodies. These three hundred bodies, more or less, that show so much motion, we conclude to belong to our fleet of stars; the others that scarcely stir on the sight belong to other fleets or fleet, separated from ours by a wide interval. The three hundred and the earth are astronomical neighbors. The three hundred and the earth are a system by

themselves — if you please, an astronomical Leonidas and his Spartans, keeping ward at the Thermopylæ of the sky, and endeavoring to beat off the crowd of Chaldean astronomers that seek to reach the very heart of the heavens. They can not be beaten off. By dint of numbers and patience, if not of boldness and genius, they shall break through. The very heart of that Greece shall be laid open.

According to the law of gravity, all the members of this system must be in a course of revolution about their common center of gravity. Where is this common center? It may be an invisible point out in the void of space, far away from any member of the system; and again, as in the case of the earth and moon, it may lie near the center of some body. The ancients always assumed the last supposition to be the true one; and further assumed that the earth is that central body about which, not only the sun and planets and comets, but all the huge varieties of nature revolve. Themselves were the center of creation. It is something in their favor that they did not know how large creation was. But the children are wiser than the sires. Since the time of Copernicus—that astronomical Columbus—men have seen reason to change their opinions on a great many subjects; on this among the rest. Now we know that the sun occupies nearly the center of motion of that system of planets and comets

to which we belong. This should have been suspected from the beginning — especially in view of the desirableness of having the only self-luminous body in the system placed somewhere near its center. And the suspicion should have been easily turned into a conviction. Suppose the earth to be practically at the center of motion. Then all the planets and comets would seem to describe, in a course of perpetual progress, regular circles about us; whereas they all, without exception, advance and retreat on most irregular curves. So the earth can not be the center. Next, suppose one of the other members of the system to be it. Then that central body, being the center of our motion, would appear to describe in unbroken progress a regular circle among the fixed stars. Now the sun is the only body in the system which fulfills this condition. Its apparent path is a regular circle; described in one year, without any retrogradations whatever; while, as I have said, every other member of the system apparently moves on a very irregular line — now forward, now backward, now sidewise, now stopping altogether — in short the picture of irresolution. More eccentric vagrants than those planets and comets seem to be, it would be hard to find. But the sun marches steadily along. He seems to know what he wants and the way to it. Right forward on the periphery of a great circle, without a step to the right hand or to the left, he

presses, till he comes around to the same fixed star again. So the sun is practically the center of the system. It is the sun, and not the earth, who is the patriarch of yonder seemingly wayward and disorderly family, and who — shall we say it — is responsible for this misbehavior. But things are not what they seem. There is nothing disorderly in the universe save intelligent beings. Could we stand at the sun, the motion-center of all these graceless nomads of the sky, they would no longer seem so indictable for vagrancy and insubordination. All their zigzags would be straightened out, all their stops and retreats would be turned into one constant advance. See how much depends on having the right stand-point for viewing things! And the wisdom of the Great Architect of astronomical systems is saved from aspersion as we see the chief source of light and heat in our stellar community so placed as to be of the greatest service to the greatest number — so placed as to oppose, as much as possible, extreme variations of illumination and temperature on any world.

But now what are these bodies thus revolving about the sun? First, we have the earth and moon — one satellite system. Next, take a telescope — a common spy-glass will answer — and bring it to bear on the planet Jupiter. You see a well-defined disc, and four bright points in its immediate neighborhood. Watch, and you shall notice these bright points approaching the planet,

crossing its face, going a little beyond it, then coming back to it, disappearing behind it, after a while appearing on the opposite side, and then receding from it as far as before; watch them, and you shall find them keeping with the planet in all its wanderings among the stars, advancing when it advances, retreating as it retreats, becoming stationary relatively to other stars when it becomes stationary. Plainly, another satellite system — a reflecting primary, with four moons waiting upon and revolving around it. There is the planet Saturn! Look at it with a more powerful glass, and see — what you shall see. If your eyes are good and your telescope is of the first class, you will by patient watching be able to detect eight bright atoms in the neighborhood of a curiously beringed disc, behaving toward it just as the satellites of Jupiter do toward their primary. Plainly Janissaries; plainly, another satellite system — a reflecting primary, with eight moons revolving around it. — Hunt up the planet Uranus, never visible to the naked eye, but seen well enough with an instrument; and, if you manage your instrument as well as Sir W. Herschel and his sister did theirs, eighty-four years ago, you will see that reflecting disc moving about with what is evidently its body-guard of six moons. Another satellite system! — So of Neptune — a newly-discovered planet. Hunt patiently in its close neighborhood, as it shines in the field of a powerful

telescope, and, if you do as well as Struve did at Pulkova, and Bond at Cambridge, you will find at least one minute point of light playing the henchman to his chief. Another satellite system! Thus it appears that we have a great system of heavenly bodies, composed largely at least of satellite systems revolving about the sun. No satellites have as yet been discovered in connection with other planets. This discovery, however, may yet be made. One has been suspected waiting on beautiful Venus. In short, we have an example of a stellar system of the second order. We have a Planet System. We have a number of heavenly sires with their comely families of various sizes about them, still bound in invisible bonds to, and in course of circulation around, the ancient and majestic grandsire — whose eye, however, is not yet dim, nor natural force abated.

Having thus found our Planet System, let us proceed to consider its chief points of interest. And, first, the order of the bodies composing it. Suppose one to start from the sun and travel to the frontiers. What body would he reach first, what secondly, and so on ; supposing them all ranged on the same side of the sun, at their average distances? At first glance it looks a hard matter to answer these questions. The members of the system seem quite too insubordinate to adhere to any order of position and revolution that may have been assigned to them. Here, is one refrac-

tory planet with its strange path; there, a still more refractory comet with its stranger; one is going this way, another that; one is creeping northward, another striding westward — in short, it is a perfect maze of positions, directions, and motions that we see. But there is a clew to the labyrinth. There is a key to this sky-cipher and hieroglyphic. And it is something that does not look particularly like a key at first sight, though it can be made, in connection with the law of gravity, to interpret, not only the order, but also the periods and distances from the sun of all the members of our system. This Rosetta stone is the average apparent daily motions, which any one, almost without instrument but with a plenty of patience, could approximately determine for himself; and which, with such instruments as every observatory is now furnished with, can be determined with admirable exactness. A word as to the general method. The law of gravity proves that the more remote a revolving body is from its center of revolution, the more slowly it must move; and, of course, the more slowly it must seem to move, as seen from that center. Hence, if we can only find how the motions of the planets and comets, as seen from the sun, compare with each other, we shall know their relative distances from that body. Now this is easily done. We have merely to find what their average motions are as seen from the earth. As we are nearer

to each by a whole diameter of the earth's orbit at one time than at another, taking the average reduces the motion to what it would appear midway between opposite sides of the orbit. Well, being thus reduced, how do the motions compare with each other? For the planets, they decrease in the following order: Mercury, Venus, Earth, Mars, some eighty small bodies called asteroids or planetoids as you may prefer, Jupiter, Saturn, Uranus, Neptune. This then is the order in which these several planets would be reached by one going outward from the sun, could they all be arranged on the same side of that luminary at their average distances. Comets would be encountered in great numbers all along the glittering journey — the best known of them in the following order; Encke's, Biela's, Halley's, comet of 1811, comet of 1680.

Such are the various places which his glittering nobles hold in that great court which the solar monarch maintains in the sky. Mercury holds the place of honor; he waits perpetually in presence. Neptune is a mere hanger-on at court — getting comparatively few rays of favor, and obliged to content himself with exceedingly distant and dim views of his sovereign. The earth has a golden mean of position — not a Steenie, in the dangerous post of a favorite putting up at the palace — not a governor-general of Van Dieman's Land and all British Antipodes — but Duke

Percy, living in an independent way on his estates in Northumberland, in a very genial temperature of court favor, neither loved too much nor too little, always welcome and never wanted, far enough from St. James's and not too far.

How long are the members of our system in traveling around the sun? The average daily motion, as seen from the sun, answers this question also. For if you find this motion to be — say 1°—you know that it will take three hundred and sixty days for the planet to accomplish the whole circumference of the heavens. If Mercury moves around the sun at a mean daily rate of 4° 5′, as it does, it will take it eighty-eight days to go 360°, or an entire circuit. And so on. In this way we find the period of Mercury to be three months, of Venus seven months, of the Earth one year, of Mars two years, of Jupiter twelve, of Saturn twenty-nine, of Uranus eighty-four, of Neptune one hundred and sixty-four. Ask that man of silver hairs how old he is. Eighty-four years, does he say? Then he was born when Uranus was last at its present point in its orbit — the point where Sir William Herschel was then finding it. The child, whose fresh, dewy orbs to-day look up wonderingly at the spangled vault where Neptune hides itself, will have grown up, fought life's battle, grown old, died, and lain in his grave a hundred years, by the time that frontier planet is able to get around again to its pres-

ent place in the sky! According to the Neptunian calendar, it is only thirty-six years since the creation of Adam! But even such years are trifling when compared with those of some comets. What think you of a voyage about the sun requiring four thousand of our years for its completion? The comet of 1811, when it last saw the earth, saw it yet dripping with the waters of the flood; the comet of 1680, when it last saw the earth, saw it without form and void, and prophesying but faintly of an Eden and an Adam still three thousand years distant. When it sees the earth again, where shall we be — ourselves, our homes, our cities, our race? May Heaven grant that the next nine thousand years shall suffice to prepare for exhibition to the gaze of that mighty voyager, the predicted new heavens and new earth in which shall dwell righteousness!

Having the periods of the members of our system, and the actual distance of one of them from the sun, we can find the distances of all the rest. For the mathematics of Newton have proved, that, in case the central body of a system is greatly superior in mass to the sum of all the others, it follows from the law of gravity that the squares of the periods of any two of them are as the cubes of their mean distances from the center. That this condition is fulfilled in the case of our own system is clear; for all observation shows that the sun, relatively to the planets and comets,

is substantially at rest. Hence the law which Newton proved is applicable to our system — the squares of the periodic times are as the cubes of the mean distances from the sun. By the help of this law and the periods, if we can find the mean distance of one planet from the sun, we can find the mean distances of all the planets. Let us then find the distance of the earth from the sun, as a means to that of every other member of the system whose period is known.

One very easy way of approximating to our distance from the sun was employed by the ancients. Sometimes a half-moon is visible during the day. At such a time let a line be drawn from the center of the sun to that of the moon, thence another line to the center of the earth, thence another back to the center of the sun — making a right-angled triangle. Now let us measure the angular distance of the moon from the sun. This, with the known distance of the moon from the earth, enables us to find with the greatest ease that other side of the triangle which is the distance between the centers of the sun and earth. But this is only a rough approximation. In these times astronomers would curl the lip at such coarse measurements as these. Why, then, not find our distance from the sun in the same way we did our distance from the moon — that is, by noticing how much the sun is apparently displaced on the sky by a given change in our place

on the earth — that is to say, by its parallax? This will do: only, on account of the exceeding smallness of the solar parallax, we can not employ the same method for determining it as was used in the case of the moon. A very accurate method, however, was discovered by Dr. Halley, the friend of Newton, and bequeathed by him to the next generation of astronomers, to be used when fitting occasion should arrive. This was the method. Occasionally the planet Venus crosses the sun's disc. Now, if we can only find how much Venus is displaced on the disc at that time by our going a given distance on the earth, we can know how much the sun is displaced on the sky by the same change of place; for the one displacement is to the other as the distance of Venus from the sun is to her distance from the earth. But this latter ratio is easily obtained from the average apparent daily motions of the two bodies, by means of that law connecting the periods and distances which has just been referred to. It is as $2\frac{1}{2}$ to 1. So, in 1769, the English, French, Russian, and other European Governments fitted out expeditions to observe, from as widely separated parts of the world as possible, the transit of Venus which occurred that year. One corps of observers went to Wardhus — a small island on the Coast of Lapland; another corps was carried by the celebrated Captain Cook to Otaheite, now Tahiti, in the South Sea. All possible means were used

to secure extreme accuracy of result. It was understood by all parties, that they were measuring a base line that would be used in determining all the other distances in our planetary system, and perhaps distances stretching across the void of space to where other isles of light, and archipelagoes of such isles, go swimming about other glowing continents in endless circumnavigations. So the science and art of the day did their very best. The extremest refinements, both of observation and theory, were brought to bear. Spider lines were split by the observer, and differentials by the mathematicians. The result was $8''\ 57$ — about $\frac{1}{230}$ of the sun's apparent diameter, — for the mean change made in the sun's place by our passing from the surface to the center of the earth. From this, by simplest triangle-proportion, was found our mean distance from the sun — 95,298,260 miles.

Taking this distance and the law expressing the relation between the distances and the periods, we come, by a simple proportion, to a knowledge of the average distances of all the principal bodies in our system. We find Mercury to be thirty-seven millions of miles from the sun, Venus sixty-eight millions, Mars one hundred and forty-five millions, Jupiter four hundred and ninety-five millions, Saturn nine hundred millions, Uranus eighteen hundred millions, Neptune two thousand eight hundred millions. Some of the comets have still greater mean distances. That

of the comet of 1811 is not far from twenty-two hundred millions of miles; while that of the comet of 1680 astonishes us with the mighty stretch of forty-four thousand millions — sixteen times the solar distance of Neptune!

You see that we have come to a new order of distances in our astronomy. The distances we have to deal with in our every-day life are such as we pass over in going to our fields, neighbors, schools, churches, markets, occasionally a neighboring city; and hours and miles answer very well to express such movements. Next, we learn that the earth we live on is nearly eight thousand miles through — this lifts us to quite another plane of distances. Our common walks and rides are lost by the side of such mammoth lines. Then we learn that the moon is two hundred and forty thousand miles away. See another plane and order of distances still! The word "miles" begins to empty itself of its meaning in such combinations. But we go on to learn that the moon is at our very door as compared with other members of our planet system — that the sun is four hundred times as remote; Neptune eleven thousand times; while the comet of 1680, that Minister of Foreign Affairs to his Solar Majesty, buries itself in that tremendous Ultima Thule whose distance is one hundred and eighty thousand times that of the moon. Do you take the meaning of such enormous intervals? Have miles any mean-

ing left to them? Does not the hight of this last plane of our astronomical arithmetic seem almost too dizzy and cloud-mixed to stand upon? And, when you are told that a car, running express from the sun to that frontier of this planetary system of ours, would not need to put on brakes for five hundred thousand years, do your conceptions seem any the less dizzy and astounded? In that great calculus which has done so much for astronomy we encounter infinitely small quantities of different orders. The zeros of the first order are of no account as compared with finite quantities — zeros of the second order of no account as compared with those of the first — zeros of the third of no account as compared with the second — and so on. In practical astronomy we have the other end of the scale — infinites instead of infinitesimals — successive orders of largeness and grandeur gradually ascending into the dizziest hights of sublimity, to each of which that below it is as nothing.

On comparing among themselves the various distances of the members of our planetary system from the sun, certain interesting facts become apparent. At our distance that luminary appears — you know how large — and so bright that you can not look at it a single moment with unwounded eyes. The brightest flame disappears when held up between it and us. At our equator men get from its disc an average temperature of 70° or

80° Fahrenheit. Now, suppose our thoughts to be chariots, and let us travel off in them toward the sun. At the distance of Mercury, the sun would appear six times larger and brighter than it did on the earth, and must be that number of times hotter — other things being equal. What a summer-two o'clock in the afternoon the Mercurians must have! If the supposed planet Vulcan were real, the sun from it would appear fifty times as large and bright as it does at the earth; and the mean heat at the most exposed parts of the planet would be more than 3000°. What a long thermometer, not to say incombustible, must the Vulcanians require! Going on still, as we near the surface of the sun, it expands so as to fill a half-heaven with its disc, and the heat is now three hundred thousand times what we have been accustomed to on the earth. Had we not had the prudence to provide ourselves with a jerkin of the very best asbestos, were not our thought-chariot itself a salamander safe of the very best quality, our traveling would now be for ever ended. But, as it is, we are able to pass around the sun; and then, speeding outward as only thought-chariots, fancy-driven, can — past belted Jupiter, past Saturn with its three wondrous rings — we stop not till we reach Neptune. Looking back, we see the sun dwindled to the size of Venus — nine hundred times less than we saw it from the earth, and nine hundred times as dim

and cold; and yet giving as much light as six hundred of our moons. And, if our courage does not fail us on these dim frontiers and with the thermometer already standing some 50,000° below zero — if it is not too much of a transition even for us, thought-pavilioned as we are, to pass, all in a single minute, from the immeasurable furnace of the sun to the immeasurable refrigerator of the very pole of our planetary system — let us keep on one stage further to where the sun appears a star of inappreciable diameter, and where, in the heart of eternal night and of infinite congelation multiplied by two hundred and fifty-six, cruises the last known picket of our planetary system, the comet of 1680. We can not deny that, if worlds thus situated are peopled, it must be with beings very differently constituted from ourselves. And what of that? We will not be guilty of the unphilosophy of assuming that the Infinite Creator has made but one pattern of living creatures, or that the patterns are not as various as the circumstances of the spheres which his almighty hand has shaped and sent whirling through the void.

You notice that I have spoken of average distances from the sun. I did this, because I did not wish to assume what is contrary to fact; viz., that the orbits of the planets and comets are circular. Instead of being circles, they are all ellipses. This does not follow from the law of gravity,

as some treatises on astronomy seem to intimate. No body revolves about another through force of gravity alone. Mere gravity would cause them to rush together on the same straight line. It takes both gravity and a projectile force across the direction of gravity to make a system of revolving bodies. The nature of the curve described — whether a circle or one of those other sections of a cone which mathematicians call ellipses, parabolas, and hyperbolas — depends on the relation which the attracting force bears in amount and direction to the projectile. Now, as we do not know what the force and direction were with which Deity launched the various members of our system into space, we are forced to rely on observation to settle the nature of the curves they describe. Let us then observe. If the orbits were exact circles, the law of gravity would cause them to be traversed at a constant pace. The apparent daily motion of the same body, as seen from the sun, would be always the same. Is it so in the case of any member of the system? In no single case, whether of comets or planets. In that of the earth, its apparent daily motion as seen from the sun — which is the same as that of the sun as seen from the earth — is observed to be quite unequal. It is also noticed that there is a variation in the apparent diameter of the sun in the course of the year; showing that we are at greater distances from it at some times than at

others. So we both satisfy ourselves that our orbit is an ellipse, and can tell just how elliptical it is. To find the exact form of the other orbits, and their inclinations if any, to our own, we can manage thus. You know that, if Cuvier found a single bone of an animal, he could build up the whole creature and picture it to you in just the size and shape with which it walked the earth twenty thousand years ago. In a similar manner, astronomers can, from a small piece of an orbit, build up the entire thing for us just as it stands in nature; give us its exact shape and size and bearing in space, in fact, a perfect fac-simile. Any piece that you can cut out of a given circle will not fit any other circle, or any other curve line whatever. Each kind of curve, and each specimen of a given curve, has its own law of curvature. The problem, then, is to get a true piece of each orbit — to find the single bone from which to reconstruct the mastodon. If you could only place yourself at the sun, and draw innumerable lines of known length to points occupied successively by a planet, you could by connecting the extremities of these lines get its real path. Now this you can do, in effect, by finding its apparent daily motion, as seen from the earth, at two times sufficiently apart to give you a sensible difference between the motions; also carefully noting the amount and direction of the motion during the interval. These elements, re-

duced to what they would seem at the sun, have certain definite mathematical relations to the lines desired, by means of which they may be drawn to any extent, and so the astronomer maps down a section of the orbit just as it stands in nature. Thus standing, that bit of a curve has wrapped up in it all the characteristics of the entire orbit, and they may be pressed out of it by the hydraulic press of rigorous mathematics. You may press out of it the eccentricity, the inclination to our orbit, the place of intersection, the place of nearest approach to the sun. In this way we can find that all the planetary orbits are ellipses, differing but little from circles, and all — those of the asteroids excepted — lying in nearly the same plane; while the comets revolve on ellipses of great eccentricity, which lie across the orbits of the planets and incline to them at all angles. In some few instances the broken pieces of cometary orbits have seemed to belong to parabolas instead of ellipses; but the observations were too rough to be reliable. If parabolas, the bodies traversing them, on going away from the sun, would never return.

Observation shows that all the planets, and all their satellites, excepting those of Uranus, revolve in the same direction, from west to east. The comets are not at all particular about following this example. Having set up in business on a principle of eccentricity, each goes off about the sun in the direction that pleases him.

How large are these astronomical neighbors and companions of ours — this sun, these planets, these comets, most of whom look so small? Have we been spending our time in considering the order and periods and distances and orbits of what, after all, are scarcely more than rounded pebbles? Having already found the size of the earth to be something considerable, we have a curiosity to see how it compares with that of our fellow-travelers about the sun, as well as with that of the monarch himself. Are we so much larger than them all that we can plume ourselves; so much larger as to give color to the ancient notion that the axis of the earth is the axle of the universe? The fact that the earth is not the center of the system discourages the idea. Also these tremendous distances from us at which our Admiral Sun is anchored and his subalterns sail, taken in connection with the appreciable discs which most of them show in the field of the telescope, give us still further inkling that they must be bodies of extreme magnitude. But let us reduce the matter to figures. How large does the diameter of the sun appear to the eye? So many minutes and seconds. What is its distance from us? So many miles. With these data, a single proportion and a single triangle give 442,840 miles for the real diameter — making a space within which might nearly be described the whole orbit of the moon. This makes our astron-

omical chief one and a half million times larger than ourselves. A very Cæsar and Charlemagne!

The process for those of the planets which have appreciable discs, as well as for all the comets, is the same; only we have to reduce the apparent diameters at the earth to what they would be at the sun, in order to use the mean distances, which are always given from the center of the system. Thus we get the following real diameters, in round numbers: of Mercury, three thousand miles; of Venus, eight thousand; of Mars, four thousand; of Jupiter, eighty-nine thousand; of Saturn, seventy-nine thousand; of Uranus, thirty-five thousand; of Neptune, thirty-one thousand. As the asteroids have no apparent discs, we do not know precisely their size; but, knowing their distances, we can make certain that none of them exceed one hundred and sixty miles in diameter. They are the infants of the planetary family — the fledglings of the planetary flock — the pinnaces and nautiluses of the planetary fleet. As to the comets; they are of all sizes, from mere specks of a score of miles across, to such a mighty cloud as the great comet of 1811 with its head of 947,000 miles in diameter, and train of one hundred and thirty-two millions in length. However, the same comet varies exceedingly in size, expanding as it approaches the sun and contracting as it retires into the frosty suburbs of the system.

So we see that, while many of our astronomical neighbors are smaller than the earth, some of them are vastly larger — so much larger that the earth is a mere babe by the side of them. But we must not fall out of conceit with our little planetary home. The bulkiest bodies are not always the best. The largest homes are not always the happiest. The largest empires are not always the most prosperous, or powerful even. Would you see a famous land? Look to little Greece, and not to mammoth China. Would you see a theater of great actions and sublime events? Look to little Thermopylæ, and little Austerlitz, and little Calvary — not to New York nor London. Still, it does undoubtedly tend to modesty in us to compare the narrow limits of our present abode with the magnificent proportions of such planets as Saturn and Jupiter, and especially of the tremendous sun! We are obliged to confess ourselves and our home mere atoms. And if we are so happy and so philosophic as to have a religious turn of mind, perhaps we shall bow our heads and say, "What is man that Thou art mindful of him!"

See now the wonderful velocities that must prevail among some of these great bodies! Knowing their mean distances from the sun and their periods, we readily calculate their average hourly pace on their orbits. Mercury moves one hundred and nine thousand miles an hour, Venus

eighty thousand, Earth sixty-eight thousand, Neptune eleven thousand, the comet of 1680, at its fastest, eight hundred and eighty-four thousand miles an hour. We have wondered at the great pace of the eagle, of the winds, of the cannon-ball, of the moon with her fifty-four thousand miles a day; and yet the moon, on her monthly journey about us, is but an indifferent traveler compared with the most leisurely of the planets. They all seem as if on some urgent errand — some errand of life and death. When one is resting his weary body from a third to a half of his whole time, and happens to think of the tremendous and remorseless activity of those great revolving spheres, he is discontented with himself. What miraculous fleetness! What if those flying orbs should, through some want of balance in the system, encounter each other in mid-heaven!

We weighed off the earth against a Scottish mountain. We weighed off the moon against the earth, by means of the tides. Can we not also weigh the other planets, and even the sun itself, in some great astronomical balance? Yes: one of the easiest things in the world — at least so far as the sun is concerned. And, first, we may weigh the sun, as we did the moon, by means of the tides. Another method is by comparing the curvatures of the terrestrial and lunar orbits. In this way, we really compare the attractions of

the sun and earth at different distances; for, of course, the degree of curvature depends on the force of gravity at the center. A simple proportion will then compare their attractions — that is to say, their quantities of matter — at the same distance; since they vary inversely as the squares of the distances. In this way we may find that the sun has three hundred and fifty-two thousand times the earth's quantity of matter. It would weigh down three hundred and fifty thousand earths! The philosopher sits with scales in his hands — as Homer says Jupiter did on Ida, to weigh the contending fates of Greece and Troy. He puts the earth into one scale, and rolls the sun into the other. Instantly the earth flies aloft with tremendous precipitation. He throws in two worlds like ours — ten — one hundred — one thousand — with scarcely better success. In a fit of impatience, he trundles all the earths he has into the capacious scallop. At last an equipoise seems establishing: the scales hang see-sawing; and, at last, settle into motionlessness at the same level. With mingled curiosity and astonishment he counts up those terrestrial globes, and finds them three hundred and fifty-two thousand in number. Knowing the quantity of matter in the sun and its size, we can find its density, or relative compactness of matter, to be only one-quarter that of the earth. In a similar way, we may find the masses and densities of all the planets that

have satellites with orbits of known dimensions. As to those planets which have no such satellites, their masses are known from their effect in disturbing the motions of their nearest planetary neighbors. For example, compare the curve which the earth when nearest Venus actually describes with that we should describe in case Venus exerted no attraction on us, and we have a measure of her attracting power or quantity of matter. So of the rest. In these ways we can reach the following results. Jupiter and Uranus have about the density of water; Mercury, Venus, Earth, Mars, a density from five to six times greater; while Saturn and Neptune have scarcely more than one-tenth of the solidity of our own globe. Though comets are so numerous — millions, in fact — and some of them occupy such immense spaces, the quantity of matter in the total of them is exceedingly small; estimated by careful men at only $\frac{1}{5000}$ of that contained in the earth. You can see stars through their trains, and sometimes through the very nuclei. They have sometimes passed very near to planets without sensibly disturbing their motions. They are mere planetary fogs. And, summing up, it appears that the sun contains more than eight hundred times as much matter as all the other members of the system put together.

All the orbits of our system are continually undergoing small changes, through the mutual

attractions of its various members. They expand, they contract, they rock, they turn completely round in the same plane, their points of intersection with our orbit travel round through the whole circumference of the heavens. This fact gave rise, years ago, to much perplexity, many hard problems, many grave fears. It was feared that these gradual changes might so combine and accumulate in process of time as to throw the whole system into disorder and wreck, dashing planets against planets in hideous concussion and disaster. At last the great geometers Euler, La Place, and La Grange, undertook to settle mathematically whether the changes in the orbits were of such a nature as to conduct to such a deplorable issue. At last the mighty problem stood resolved. It was found that, in the particular case where the central body of a system is vastly heavier than all the rest, and all the planetary orbits nearly circular, and nearly in the same plane, and traversed in the same direction — all of which features, as we have seen, belong to our system — there are two things about every orbit that can never change; viz., the greater axis and the period. For example, our mean distance from the sun, as found for a single revolution, can never vary; nor can the length of our true year. Next, it was proved that in such a system all the changes that do occur must be periodical, flowing and ebbing like

the tides of the sea — enlarging for perhaps millions of years, and then returning to the old point. So the stability of the system stands demonstrated. It has in itself no seeds of death. The invisible bonds of the law of gravity hold the amazing leviathans of the sky so strongly and surely that they can not escape from their spheres. The system was built capable of standing for ever. And yet how easily it could have been otherwise! Suppose the sun had not been made vastly heavier than all the other bodies; suppose Deity had not so tempered the projectile force, in amount and direction, to the force of gravity of each planet as to make it describe nearly a circle; suppose he had shot off the planets at all sorts of angles with reference to each other — and he might have done each of these things; indeed it required care not to do them — then the system would have been unstable, and, sooner or later, our whole Congress of worlds would have gone plunging together in frightful and unutterable catastrophe.

V.

HIGHER SYSTEMS.

V. HIGHER SYSTEMS.

FIFTH LECTURE.

HIGHER SYSTEMS.

AS an example of the Satellite Systems, I have described the earth and the moon. As an example of the Planet Systems, I have described our sun with its revolving planets and comets. We come now to systems of the Third Order — Sun Systems — each of which consists of two or more planet systems revolving about their common center of gravity.

More than six thousand fixed stars, so called, that appear single to the naked eye or to some powers of the telescope, are found to consist, each of several stars, when proper glasses are brought to bear upon them. Some are double, some triple; and in one case six stars are found to make up what appears a single star to the unassisted eye. The list of these compound stars enlarges every year. Recently, a very important addition has been made to the list by the discovery that great Sirius, the glory of our winter nights, is double.

An American has the honor of this discovery, and of receiving for it the La Lande prize from the French National Institute.

It is to certain of the double stars that I would first ask your attention. Look at the bright star Castor. Had you a good telescope bearing on it, you would find it to consist of two nearly equal members. And, could you follow from year to year the bearings of these two members with respect to each other, you would, in time, find one of them in course of revolution about the other — just as the moon is about the earth, and the earth about the sun. What does this mean? Why, it means one sun with its attendance of planets revolving around another sun with its attending planets. That these stars in Castor are self-luminous bodies we know from the character of their light, as well as from the impossibility that bodies shining by mere reflection of light from our remote sun or from any neighboring star equally remote, should be visible at such vast distances from us as all the fixed stars must be. That each of these suns is the center of a planetary cohort that brilliantly escorts him on his way, we infer from the analogy of our own system and from the wisdom of the Creator. When we see a lamp in a house, we infer the neighborhood of some persons who need the light; when we see the piercing Fresnel blaze of the light-house pouring far and wide across the darkling seas, we believe in

roving ships to be guided and benefited by it; and when we lift our eyes to where a sun blazes as a celestial Eddystone through pitchy space, we conclude that there are bodies needing to be lighted and cheered by its beams, just as the bodies of our planet system need to be lighted and cheered by our solar orb. Thus we have a new and higher order of systems for our astronomy. Behold a sun revolving about a sun, a planet system about a planet system; necessarily, two planet systems about their common center of gravity.

Now more than a hundred such pairs of stars have been caught in the act of revolution. The Pole Star is one of them. A famous star in the Constellation of the Swan, known as 61 Cygni, is another. In the case of some of these stars, a complete revolution has been accomplished since attention was directed to them; in one case, two full revolutions have been completed. But these revolving suns are not confined to sets of two. There are sets of three, of four, of more stars — in each of which the members have about the same brightness and distance from each other, and are in the course of years observed describing curved lines among themselves. Evidently, more systems of the third order — suns with their escorts of planets revolving, without any intermediate motions, about their common center of gravity. In addition to these systems whose revolutions we see, there are multitudes of others whose revolu-

tions we do not see, on account of their distance or slowness; but of which we are just as certain as if we saw them. Since the beginning of the century, has ripened one of the most important of the sciences, under the name of the Calculus of Probabilities — a branch of that subtle and powerful Differential and Integral Calculus which has served the Prosperos of astronomy, not only to put a girdle around the earth, but also around the whole visible heavens. According to this science, there is no chance worth considering, that any stars, optically so close together as to appear single to the naked eye, are not actual neighbors in space, and so in course of mutual revolution. This principle gives us more than a thousand additional sun-systems. But these are not all. Many stars that do not appear single to the naked eye are proved to constitute similar systems, by the identity of what are called their proper motions. Thousands of stars are found creeping along the sky, not on curves, but on straight lines. The progress is exceedingly slow — scarcely averaging more than $\frac{1}{18,000}$ of the moon's apparent diameter per annum. Now, whether this is due to our own motion, or to that of the stars themselves, or to both, it could not be the same both in amount and direction, in the case of two or more optically near stars, without their being actually near each other in space, and so forming a mutually revolving system. This principle en-

ables us to make another large addition to the number of our sun-systems. Yonder are Mizar and Alcor, two stars in the tail of the Great Bear, more than a third of the moon's diameter apart, which are thus proved to compose a sun-system. They are creeping across the sky in company; going in just the same direction, and at just the same pace. From satellite neighborhoods we have risen to planet neighborhoods; and now, from these, we have evidently risen to grand solar neighborhoods, where orbed suns go grandly wheeling about suns, carrying with them in inseparable union their glittering retinues.

How far from us are these sun-systems? At one time astronomers almost despaired of being able to answer this question. They found that the method used for finding the distances of the moon and sun from us would not apply to the fixed stars. No change in our place on the earth, though it has a diameter of eight thousand miles, caused the slightest change in the apparent place of any of those twinkling points. If we could only travel off two or ten times eight thousand miles on a straight line! Well, can you not — do you not? Do you not, every year of your life, make a vastly greater travel than that? Is not the earth sailing away with you about the sun at the rate of sixty-eight thousand miles an hour, and so at the ends of every six months putting you at the opposite extremities of a straight line

one hundred and ninety millions of miles long? So observers set themselves to see whether such a monster base line as the diameter of the earth's orbit would make any impression on the places of the fixed stars. Their triangles informed them that in case a star should be displaced on the sky less than the eighteen-hundredth part of the moon's apparent breadth, by their going that immense distance, it must be more than one hundred thousand times that distance from them. And they could not find any star that showed a clear annual displacement of even that small amount. So they put up their bulletin, and informed the world that no fixed star could be nearer to us than one hundred thousand times one hundred and ninety millions of miles. A most bewildering distance! It would take light itself, that fleetest of known travelers, that Mercury of science, whose pace is one hundred and ninety-two thousand miles a second, more than three years to sweep across it. Here it was feared our knowledge must end. We could tell the point from us within which the fixed stars could not be; but their actual distances, who could ever know? But Providence was kind. It gave the world, at length, a Bessel to bridge over that tremendous chasm between us and the sun-systems of remote space, and set up mile-stones along it — a man who found himself able to measure a smaller bit of the sky than one second, who found that by

management he could make sensible in his astronomy even so trifling a fraction as the thousandth part of a second — a man who could not, indeed, like one of his countrymen, write himself, "By the grace of God, King of Prussia," but, what was far better, who could write himself, "By the grace of God, King of Prussian astronomers." He found that, by going over the whole diameter of the earth's orbit, one would alter the apparent place of the double star 61 Cygni about one-third of a second. This makes its distance from us three hundred thousand times one hundred and ninety millions of miles — an interval which it takes light nine years to traverse.

This was in 1838. Since then, about forty stars have yielded up their distances from us to our curiosity. The nearest sun-system yet found belongs to the southern hemisphere — Alpha Centauri, the brightest star in the Centaur, and indeed in the whole southern vault. This is only one-third as remote as 61 Cygni. The Pole Star system, on the other hand, is five times as remote — one million five hundred thousand times one hundred and ninety millions of miles. The mariner and the fugitive have used light to guide them on their way which has been forty-six years in coming to them for that purpose.

One would like to know how large these revolving suns are; how they compare in this respect with our sun. If they showed real diame-

ters under the telescope, we could at once make the comparison. But they do not. So we are driven to another method of a less satisfactory kind, but still one that will help us to some just idea of how the different suns of space compare with each other in magnitude. Delicate instruments have been invented for measuring the relative amounts of light from the heavenly bodies. With what is perhaps the best of these instruments, it is concluded that we receive twenty-two thousand million times the light from our sun that we do from the sun-system Alpha Centauri. But that system is two hundred thousand times further away. Hence it follows, that, if it were brought as near to us, it would give a little more than twice as much light as our sun; that is, each of the two nearly equal suns that compose the star is about equivalent, in the matter of light, to our luminary. In the same way we find that the 61 Cygni system gives about half as much light as our sun; making each of its two nearly equal members equivalent to a quarter of our sun. The Sirius system is equal in light to sixty-three of our suns; the Pole-Star system to eighty-six. In each of these, the two stars composing the system differ exceedingly from each other in brightness, and the larger star must be credited with most of the brilliancy. Think of an eighty-fold sun! However, some stars are still more astonishing; Vega, for example, which blazes with the light of three hun-

dred and forty-four suns; Capella, for example, which blazes with the light of four hundred and thirty; Arcturus, for example, which blazes with the light of five hundred and sixteen; Alcyone, for example, which blazes with the light of twelve thousand! As we have seen, our sun is no trifle. Its astonishing orb would nearly fill the whole lunar orbit; and would weigh down, eight hundred times over, its whole ponderous cortege of satellites, planets, and comets. And yet it is only one of the lesser lights of space. Not the smallest, indeed — forbid it, little 61 Cygni — but still a mere rush-light and glow-worm as compared with many of the huge luminaries which pour their glories adown the immensity of nature. It could not remain visible a moment in the presence of such golden-haired and majestic day-kings as even Sirius and Polaris to say nothing of those huger monarchs whose effulgence floods the celestial spaces.

Knowing the distance of one of the systems from us, we can find how far apart its members are at any time, by observing the apparent distance between them. The two suns of Alpha Centauri are apart by only seven diameters of the earth's orbit — something less than the distance of Uranus from our sun — so that planets belonging to the system will sometimes have two suns above the horizon at once, while at another time one sun will rise while the other sets. The two

suns of 61 Cygni are apart by twenty-one diameters of our orbit; those of the Pole Star by one hundred and five diameters; Mizar and Alcor by at least five thousand diameters — five thousand times one hundred and ninety millions of miles — a line on which could be ranged three hundred and sixty planet-systems like ours.

Several of these systems having made entire revolutions since they began to be scrutinized, we may be said to have seen their periods. Others have advanced so far on their orbits that we can readily estimate the times required to accomplish the remainders. And others still have been under observation sufficiently long to furnish us with very considerable pieces of the curves they describe; from which, like the naturalists, we can build up the entire orbits, and press out of them by our powerful geometry all their characteristics — among other things, the periods and ellipticities. The periods differ among themselves wonderfully. One is forty years; that of Alpha Centauri is seventy-seven years; that of 61 Cygni four hundred and fifty-two; another three thousand; and that of Mizar and Alcor must be something like two hundred thousand years! Wonderful year of two hundred millenniums! Wonderful orbits also, as far as observed — wonderful for their ellipticity! In one case, that of Alpha Centauri, the orbit is five times as long as it is broad. What extremes this means may be seen from the

case of Halley's comet. This body has an orbit four times as long as it is broad; and the consequence is, that, while at one point it approaches the sun as near as Mercury, at another it recedes from it six hundred millions of miles beyond Neptune — the least distance from the sun being to the greatest as one to eighty-five. Such variations would be fatal to an inhabited earth; but to a sun, that movable furnace that carries its own light and heat with it wherever it goes, what matters it how far it strays off from its central orb into the cold of space — to a sun that is never at less than white heat, what matters it if it sometimes gets a good deal whiter! We may be sure, however, that those sun-systems which consist of three or more suns do not contain such eccentric orbits. It would be inconsistent with their stability. As our planet system would fall to ruin were not its orbits nearly circular, nearly in the same plane, and controlled by a force at the common center of gravity greatly superior to any individual force in the system, so would every higher system made up of more than two members.

Before dismissing these sun-systems, I must say a word as to their color. All the colors of the rainbow are represented in them. Some systems are white, some blue, some red, some yellow, some green; and this, you will observe, means differently colored days for the planets of those

systems. Castor gives his planets green days. The Pole Star gives his yellow. There are more than sixty blue systems, one of these consisting of a great number of members. In the southern hemisphere are stars, yet to be found double, which in the telescope look like drops of blood — all about the constellations of the Cross and Altar, as if to gloriously symbolize the sprinkled blood of our redemption. Also the suns of the same system often have different colors; one shining like an emerald, another like a ruby, and perhaps a third like a sapphire. And, as if to make that Southern Cross the fairest object in all the heavens, we find in it a group of more than a hundred variously-colored red, green, blue, and bluish-green suns, so closely thronged together as to appear in a powerful telescope like a superb bouquet, or piece of fancy jewelry. Let no one say that the Creator, who makes gems and flowers for the earth, and sets gems and flowers in the sky, cares not for natural beauty: though it be most true that the 'beauties of holiness, especially from the womb of the morning, when thou hast the dew of thy youth,' are still more precious in his sight.

GROUP-SYSTEMS! Near the bright blue star Vega is a star which the telescope finds to be quadruple. The four stars are arranged in pairs — the pairs being many times further apart than

are the individuals of each pair. The whole form a system by themselves; as is shown by the sameness in amount and direction of their proper motions. But, grouped as they are, the law of gravity requires each pair to revolve around its center of gravity, and then both pairs about their common center of gravity. The revolution is not seen, as in the case of many double stars; but we are just as sure of its reality as if we saw it.

In Orion is a star which the telescope finds to be sextuple. The six stars have all the same proper motion, and so are neighbors in space. Four of them are at about the same distance from each other; but two of these have each a small companion much nearer to it than are the others. The law of gravity requires each pair to form a revolving group by itself, and then all the spheres to wheel about the common center of gravity of the whole. That superb wheeling is not seen, on account of distance; but we are just as sure of it as if we saw it. Another Group-system!

Look at the famous and beautiful Pleiades! Gathered about the brightest star of the group Alcyone, the telescope sees fourteen conspicuous stars. These are all creeping along the sky, equally fast and in the same direction. The calculus of probabilities assures us that the chances are hundreds of millions to one against their being merely optically connected. They form

one grand astronomical neighborhood in space, around whose center of gravity they all revolve; one grand company of celestial navigators, exploring their way by unerring instinct, without chart or compass, through trackless space. But, if you should see a map of these fourteen stars, you would find them distributed into several groups, each of which must contain its own center of revolution, while all these centers must be borne in majestic sweep about the gravity-center of the whole sparkling family. Invisible orbits within orbits; but as certain as if we saw their fiery ellipses burnt into the dark concave of evening! The distance of this group-system from us has been determined by the determination of the distance of Alcyone; and is twenty-five million diameters of the earth's orbit. Were the Pleiades this moment blotted out of existence, they would still blaze away in the neck of Taurus for more than seven hundred years; for that is the time spent by light in passing from that system to us.

These specimens of the group-systems must suffice. We pass to the next higher order — CLUSTER SYSTEMS.

There are thousands of small roundish spots on the sky which, when examined by telescopes, prove to consist of crowded stars; sometimes uniformly distributed; in other cases, gradually

becoming denser till all individuality is lost in a general blaze of light at the center; and in other cases still, arranged into several nuclei which lie quite evenly over the mottled face of the cluster. On examining the nuclei carefully, they are sometimes found to consist, each, not of a single group, but of a cluster of groups. Behold systems of the Fifth Order! The artificial form of each general cluster, and the chasm of black space all around it, show that it is a system by itself in space, with its one center of revolution for all the nuclei. Then each nucleus has its own subordinate center for all the groups composing it; and next, each group has its still more subordinate center for all the suns composing it. Many of these great systems must contain from ten to twenty thousand stars each. Think of a system made up of twenty thousand revolving suns; each sun with its planets occupying at the same time a three-fold orbit, and spinning at once around three widely separated centers — first, around the center of the group; next, around the center of its cluster of groups; and then, around the center of the whole great cluster!

As an example of these cluster-systems, I instance a cluster found in the constellation Hercules. It is famous among astronomers as being the grandest object of its class in the whole heavens. When Sir William Herschel saw it for the first time through his great reflector, it

almost made him leap, with mingled astonishment and delight. An eminent astronomer doubts whether any person ever saw it for the first time, through a large telescope, without a shout of wonder. Certainly it is an object of wonderful glory, — that golden shield of packed suns! Shall we call it the ægis of immortal Jove? Call it, rather, the flaming buckler of the Christian Creator, hung out for sign on heaven's blue battlements, and on whose thick bosses those men insanely rush who, in the face of the stars, presume to doubt Almighty God! The first Herschel, sounding the heavens with his telescopes, concluded this cluster-system to be deep in the abyss several hundred times the distance of the nearest fixed star — say some two thousand years, as light travels. Its locomotive suns, with their long trains of planets, do not, at such a distance, render to our eyes those mighty three-fold curves on which they are rushing; but we are just as sure of their reality as though we saw them — saw them as we see the orbits of binary stars — saw them as we see the track of the rocket when it describes its flaming parabola through the air.

We advance another step, to systems of the Sixth Order, — NEBULA SYSTEMS!

Scattered, or rather arranged, over the sky by thousands are those bright-misty spots, called nebulæ, which no power of the telescope has yet

been able to resolve into stars. It has been claimed that they do not consist of stars, but only of a sort of fire-mist, out of which suns and planets and satellites are in process of being made by natural law. There are many objections to this view. But it is enough that there is not a single proved case of such fire-mist in space; that the hypothesis is altogether unnecessary to account for the facts observed; and that nebulæ, apparently as irresolvable as any, have, by improvements of telescopes, been turned into clusters of stars. In my view, they all consist of stars, so packed together by local neighborhood and unspeakable distance that all individuality of impression on the eye is lost. They are found in great variety of singular and beautiful forms — sometimes perfectly round, sometimes oval, sometimes lens-shaped, sometimes ring-shaped and even consisting of a series of concentric rings. One beautiful nebula resembles a crab; another, a fan; another, an hour-glass; another, a whirlpool, whose eddies are made evident to the eye by, as it were, floculi torn from the famous golden fleece of Colchis. Some of them are perfectly continuous and uniform in appearance. Others are "spotted as a pard," with numerous centers of condensation: while others still are broken up into more or less distinctly separated nebulous patches; like a defeated army whose great corps are just in the act of separating to-

ward all points of the compass. The great fragments of these routed nebulæ appear in the best telescopes very much as the cluster-systems do in the smaller — that is to say, dappled with nuclei pretty evenly distributed. They are evidently cluster-systems. And, taken together, they form a revolving neighborhood in space, of another order still higher — a Nebula System in which nebulæ of clusters of groups of suns sweep their, at least, quintuple orbits in harmonious combination around the gravity-center of the whole nebula.

What is the Milky Way, so called, which we see belting our heavens? Nothing but the nebula to which we belong, expanded all round the sky and easily resolved into stars by the fact that we are in the midst of it. A little observation and reflection suffice to show that its shape is that of a thick mill-stone, with its rim split in the middle for about a third of its length and somewhat opened. Our place is near the plane of this cleavage, but considerably one side of the center. When we, from our place in this cleft wheel of stars, look off in the direction of the circumference, the stars appear very numerous; when we look toward the sides, we see comparatively few. All the scattered stars, all the groups, small and large, that we see in any direction, belong to our Milky Way — to our nebula. They are nearer to us than any other stars in space. All the stars whose dis-

tances have been determined, all the multiple stars whose orbits have been observed, all the stars whose proper motions have been noticed, are as much part of our Milky Way as the milkiest part of it. All the examples of astronomical systems which I have hitherto given, at least up to the cluster-systems, were from this same nebula of ours. And cluster-systems themselves can be easily supplied from it. If you will scan on some favorable night the remoter parts of this white Wonder, you will find that it is by no means a continuous nebulous zone, but rather a succession of star-clouds, many of which are mottled after the manner of the cluster-systems. And such they are. The whole, from satellites to sun-clusters, are in process of revolution about the great forceful heart of the nebula. We know it must be so, in advance of all observation. But in this case it is thought that observation has made assurance doubly sure. First, our sun is in motion — like Castor and Polaris; like the thousands of stars that show proper motions, and, in part, because they show them. A wonderful thing has been noticed in that part of the heavens that is now passing over our meridian southward from the zenith; the region occupied by Orion, the river Po, Sirius, and especially the Dove. It has been noticed that the stars in this region are gradually drawing together, just as the ships of a fleet would seem to do to one sailing away from them; while

at the opposite quarter of the sky the stars are gradually separating, just as the ships of another fleet would seem to do to one sailing toward them. Great Hercules is yearly becoming huger and brawnier; his club, and especially his bow, growing every year more formidable. This has been going on now for a great number of years. Of course, there is but one explanation. Our sun, with its retainer-worlds about it, is sailing away through space toward Hercules, on an orbit so vast that the part of it which has been described from the date of the earliest accurate observations does not differ sensibly from a straight line. At last, however, we shall double the wondrous cape of our great ellipse; and then the Dove will begin to expand and plume her heavenly wings, while champion Hercules will dwarf behind us. But this does not determine where the center of motion is. Where is it? Astronomers have sought to answer this question, and apparently not in vain. By methods which can not now be explained, it is found that Alcyone — most beautiful star of the beautiful Pleiades — is the center of our motion; and that we are moving about it at the rate of more than thirty-three millions of miles a year, on an orbit whose diameter is fifty million times larger than that on which we move about the sun. As the distance of Alcyone is approximately known, we can find our period. It is only about twenty millions of years.

Such is our sun's center of motion. And the celebrated Mædler has shown that it is also the center of a great number of other suns — in fact, that the proper motions of the stars in all quarters of the heavens conform to the idea that they are spurring in glorious curriculum around the same point. He concludes that Alcyone is the center of the whole nebula. And though the English Astronomer Royal has recently dissented from this conclusion, and though we certainly are not authorized to claim for it the most absolute proof, yet it is probably as much like the truth as most photographs are like the persons who sit for their pictures to the sun.

Mysterious continental islands of the remoter heavens! Greatest empires of suns that have yet sent greeting light to us! There ye lie to-night, seemingly steeped in breathless quietude and uttermost sleep, where the earliest observer saw you: and yet what mighty race-courses are those on which your orbs go panting their eternal rounds about the great nebular heart! Why, let us measure two of these celestial Astrodromes. According to the best estimates of our own nebula it contains some eighteen million suns; and the thickness of its golden wheel is about eight million diameters of the earth's orbit, while its diameter is one hundred and seventy million such diameters. One of its Border States would require not far from one hundred millions of years

to put orbit about metropolis Alcyone; and, though so remote, has never been in danger of parting company with us. There is the oval nebula of Andromeda, just visible to the naked eye and yet giving no sign of resolvability in the six-foot speculum of the Earl of Rosse. A nebula of which such things are true, is easily shown to be so far away that the light by which we see it must show it as it was at least a million of years ago, instead of as it is to-night. The rays have been all that time charging across the void at the rate of 192,000 miles a second. At such a distance, its apparent diameter, half that of the moon, means for the nebula a breadth of thirty thousand years — the fifty-three foot reflector being surveyor-general, and a light-sprite carrying the chain.

We have found all the suns, and groups of suns, and clusters of groups of suns, in each nebula, engaged in revolution about its center of gravity. Is this center itself in motion on another orbit still larger? Is each nebular fleet, instead of riding at anchor in the sky, sailing away on a circumnavigation more stupendous than any we have yet noticed? It is even so. There are ULTERIOR SYSTEMS. We find nebulæ disposed in groups of two or more; of about the same brightness, coming into view with about the same power of the telescope; evidently belonging to the same order of distances from us. Just as there are

double and multiple stars, so there are double, triple, quadruple, quintuple, sextuple nebulæ; and recently D'Arrest, a Danish astronomer, has announced that he has actually caught a nebula in the act of revolving about a nebula. Very likely he is mistaken; it seems as if he *must* be; in any event, we need no such ocular demonstration. We have long been as sure of revolving nebulæ as if we had seen them — sure of some Alcyone, 12,000 suns strong, revolving about another Alcyone, perhaps 100,000 suns strong. More than this. The Magellanic Clouds, so called, of the southern hemisphere, are nothing but two great beds of clusters and nebulæ; three hundred nebulæ in one, and thirty-seven in the other: and in the constellation Virgo, especially in one of its wings, the nebulæ are scattered almost as the grain will be sown in your fields this spring — swarms of them, in groups and clusters of groups; and it is just as certain that each of these great beds is in course of revolution about its center of gravity as it is that over that amazing congeries of firmaments is stretched the scepter of law.

Mightiest of astronomical neighborhoods yet seen! What wondrous outskirting orbits have we here — what abysses of periods — what year Great and Wonderful in which some picket sun of one of those picket nebulæ spins out its ellipse about the whole nebulous stratum to which it

belongs! What abysmal grandeurs of motion are piled and compacted within that circle of 20° diameter about the wing of Virgo! The ancients did not know what wonders were swarming in this region; and, had they known, they could hardly have covered its flying hosts with a more appropriate symbol than they have done — a broad celestial wing. You easily understand the utter inadequacy of figures, whether expressing miles or diameters of the earth's orbit or the largest measured distances of fixed stars or years of light-motion even, to express the dimensions of this Titanic nebular system.

Such are the various orders of systems which we can prove to be within the range of our telescopes. But no astronomer doubts that within this range may lie hundreds of different orders, wheel within wheel, in astounding climax and bewildering complexity: even that within this range our own earth may be describing a thousand-fold orbit about a thousand different centers.

But there must be, at last, a UNIVERSE SYSTEM — a system composed of all the bodies that people space, and in which each body revolves about the gravity-center of the whole material universe. Let us devote a few thoughts to it.

Eighteen million suns belong to our firmament. More than four thousand such firmaments are visible; and every increase of telescopic power adds to the number. Where are the frontiers —

the last astronomical system — that remote spot beyond which no nebula, no world, glitters on the black bosom of eternal nothingness? Probably, some one of those many nebulæ just brought into faint view by the great reflector at Rosse Castle, is but another nebula of Andromeda; which, though visible to the naked eye, gives no sign of being resolved into stars by an instrument of four hundred times the eye's space-penetrating power. Think of the distance expressed by four hundred times the distance of the milky way of Andromeda — five millions of years, as flies the light! Alas, how feeble are our powers! How they labor and bow under the weight of such mighty numbers — such gates of Gaza! What wondrous chronometers those must be which could take fitting account of the ongoings of such far-off firmaments! Could you stand, with a wand in your hand reaching to that remotest galaxy, and sweep it around you in every direction, what an empire fit for a Jehovah would fall within the embrace of those glorious circles! And yet who shall say that even this is the whole astronomical universe? What right have we to stop just where the power of our instruments happens for the moment to have stopped, and say, "This is the end — these are the Pillars of Hercules? Turn back, O adventurous explorer — nothing but night and void in this direction — thou hast reached the last outpost of the kingdom of the Eternal! *Ne plus*

ultra!" No: thrice no. On still through peopled infinitude, through raining galaxies and tornado-nebulæ; and, while thou goest outward still through the charging, storming hosts of suns as long as thought can fly, or angels live, say ever to thyself, "Lo, these are parts of his ways; but how little a portion is heard of him! The thunder of His power, who can understand?" Is not space infinite? Is not He infinite? And who dare say that his works are not wellnigh infinite too — at least that the limit to which our gasping and bewildered astronomy has hitherto conducted us is not, as it were, but the first mile-stone of peopled space; and that great swarming sphere which our mightiest telescopes have gauged, but the merest rain-drop compared with another swarming sphere which embraces it? But let us suppose an end; suppose an orbit so large as to include in its unspeakable round the entire magnificence of the sidereal heavens. At last the Ultima Thule is reached. We have the total universe of matter which God has made — one all-comprehending astronomical neighborhood — and around it stretches in all directions the black wastes of an altogether endless vacancy. All members of this great ultimate system must be in motion about its common center of gravity. Whether this sublime center is, or is not, a mathematical point, where not an atom of matter nestles, our present science has no means of determining. But is there not some-

thing at the bottom of our hearts better than science, which invites us to believe that what would be so fitting and beautiful is also triumphantly actual; namely, that at the center of this august totality of revolving orbs and firmaments — at once the center of gravity, the center of motion, and the center of government to all — is that better country, even the heavenly, where reigns in glory everlasting the Supreme Father and Emperor of Nature; the capital of creation; the one spot that has no motion, but basks in majestic and perfect repose while beholding the whole ponderous materialism which it ballasts in course of circulation about it. All hail, Central Heaven! All hail, innermost Sun Palace and celestial Alhambra! All hail, believer's Last Home — from which an adult astronomy, fitted with the pictured and dynamical wings of angels, shall immortally radiate to all the girdling worlds and immortally bring home fresh proofs of the glory of Him who has so long been defrauded of His rights among men of science by the empty names of law and nature!

VI.

AUTHOR OF NATURE,

AS RELATED TO ITS LEADING FEATURES.

VI. Author of Nature,

As Related to its Leading Features.

SIXTH LECTURE.

AUTHOR OF NATURE.

IS there an *Author of Nature?* Hitherto, the affirmative has been steadily assumed; and I hope that at this point such a question seems almost an insult to your understandings — freshly returned as they are from sweeping through the unutterable glories of the astronomical universe.

Still, let the preposterous question be entertained. We are not likely to realize too vividly the existence of an invisible Divinity. Though we are not atheists; though we would be shocked to receive that dreary and awful name; though perhaps it has never once occurred to us, with our Christian training and surroundings, to doubt that this glorious nature about us has the God of the Scriptures for its Father and King, we still belong to that fallen race whose strong and universal tendency is to be without God in the world.

Theists and atheists agree as to the advantage of approaching the question of a Divine Being

with a mind freshly steeped in the leading facts and courses of nature. The atheist claims that nature makes on minds thoroughly imbued with her spirit an impression adverse to faith; and points in evidence to some eminent cultivators of the physical sciences who have been as skeptical as they have been scientific. So he is in favor of the study of nature. On the other hand, the theist is in favor of it for the very opposite reason. He denies the atheism of science. He refuses to infer it from the unbelief of some French and German philosophers — with here and there a second-rate English disciple — whose minds from childhood have been poisoned with the writings of Voltaire and his school, who have seen around them only a grotesquely corrupted form of religion, and whose private lives for the most part were such as to make it greatly for their interest to have no God. To him the case of such exceptional men only shows the exceeding force of native depravity, evil training, evil surroundings, and evil habits, at withstanding the natural tendency of their pursuits. This tendency he regards as strongly theistic. He thinks he sees premonitions, prophecies, presumptions, and even proofs of Divinity in the great universe that expands around him; and believes that, other things being equal, the more fully one comes under the influence of the astronomy, the geology, and the other branches of natural

science whose findings have amazed mankind, the more easily he will admit and the more strongly he will hold, the doctrine of a Divine Being.

What all classes think it well to do, let us attempt. We will attempt to place our hearts still more fully *en rapport* with nature. We will, if possible, get them into yet closer communication and sympathy with its great leading facts and courses. These are chiefly astronomical. Yet I shall not restrict myself to astronomical facts, technically so called, but shall allow myself to gather from the whole of that broad field of science of which astronomy is the undisputed and all-comprehending Chief. And I can not but think that the effect will be to preclude objections, to furnish presumptions, and generally to dispose the mind to a mighty faith in God. I am persuaded that any man who can be fairly set down in the midst of nature, and thrown honestly open to all its subtle inductions, magnetisms, inspirations, will silently drink in theism, as a fleece spread out under the stars drinks in the dew.

Suppose it claimed that a certain veiled painting is the work of Titian. If, on gradually lifting the veil, we find exclusively trait after trait such as might have been expected in a work by that great master, our disposition to think favorably of the claim increases with every step: and if, when

the canvas is entirely exposed, every leading feature seems Titianic and the whole worthy of such an author, our minds are far advanced toward faith — they are in a state of high preparation for any ulterior evidence, and only comparatively little of it will be required to secure full conviction. And this is reasonable. Previous to examination, how could we be sure that there were not lurking under that veil incompatibilities, or at least disagreements? Now our uncertainty is removed. We have found positive harmonies. The facts match the claim. The picture is such as might have been expected from Titian — such indeed as he would surely have painted. His great characteristics are strikingly here. And these are so many verisimilitudes, so many presumptions in favor of the claim: and, in the absence of all evidence to the contrary, at least authorize the critic to stand at the very verge of assent, facing it kindly and with foot uplifted, ready to cross the border at the first competent invitation. Let such an invitation come in the shape of an assurance that the painting is almost universally accepted as the work of Titian, especially among the most intelligent and fair-minded judges; further, that the hypothesis which ascribes the work to him is, as compared with other hypotheses, altogether the simplest, the least embarrassed, the most useful, as well as the most historical — this would and should plant his feet in the very center of faith.

Now it is claimed that nature is the work of God. Let us, step by step, unveil its leading features and see if they do not strikingly harmonize with the claim: and, as they may be found to do so, let unbelief approach its frontier; and, when at last the general scheme of nature appears characteristic and worthy of God, let the traveler at least stand on the last boundary of his chill and somber territory, all ready to cross with decisive and ringing step into a brighter land at the first summons of the positive evidence.

What I propose, then, in the present lecture, is to illustrate the general harmony between nature and the doctrine of a God. Of course, a few specimen illustrations are all that can be offered. One will do well to feel the pulse of nature still more fully in the works of Ray and Good and Paley, in the Bridgewater Treatises, and in later works of the same character.

One of the most striking features of what we call Nature is its vastness.

I do not forget that I am speaking to those who have become familiar with the wonders of physical science. But neither do I forget that even the scholar must refresh his impressions of things in very much the same way with other men. So I ask you to think of plains stretching to the horizon; of mountains piercing the clouds; of roomy continents anchored in roomier oceans; of this whole earth-sphere, with its huge baldric of twenty-five

thousand miles, covered with innumerable vegetable products, peopled with men to the potential figure of a thousand millions, swarming still more potentially with the lower animals, and so flooded with microscopic life that almost every cubic inch of air and water and soil is panting with an incalculable population, — some of whose smaller individuals multiply themselves into one hundred and seventy billions in four days; gather their five hundred millions in a single drop of water; and yet make up, with the stony cerements of the merest fraction of their fossil ancestry, whole mountains and geologic beds. Such is our world. Out in yonder vault, find that millionfold world which we call the sun, with its invisible retinue of a hundred earths; out in yonder vault, when night falls, find a thousand suns similarly attended; with tube Galilean, thousands more; with tube Herschelian, millions more; with tube Rossian, billions more. Is this the end? What astronomer for one moment imagines that another enlargement of the great speculum at Parsonstown would show our vision to be already hard up against the frontiers of nature? Not even Darwin doubts that successive improvements in the space-penetrating power of our instruments would go on indefinitely opening up firmaments at every step. Where is the verge of the universe? Who would undertake the roll-call of its orbs? Who dares

to say that he could count through the grand total of its firmaments, even though he should count a thousand years? Figures go but a small way toward expressing the dimensions of such a universe — whether one considers the number of its worlds, or the expanse of space through which they are distributed. Our world spins round its ellipse, of well-nigh two hundred million axis, without ever having a neighbor nearer than thirty millions of miles, save its own moon. The interval between our sun and the nearest star of the same galactic nebula is twelve hundred thousand times this distance. And then the distance from nebula to nebula — it is absolutely awful. Our telescopes sweep a sphere of stars whose diameter is seven millions of years, as light travels. Calculation covers its abashed face with its great wings in the presence of these overwhelming amplitudes. And such is nature!

Certainly such a universe as this does not cry out *against* the existence of a God whose essential attribute is immensity. On the contrary, it is just such a universe as one would have *expected* to come from such a being. Nay, given a Deity who is practically at home in every point of space, whose attributes are laid out on a scale of unbounded vastness, to whom it is just as easy to make and govern a trillion of worlds as it is a grain of sand, and the imperial fitness of things would *demand* that he people vacancy with very

much that profusion and breadth of being that we actually see. The work ought to express and honor the workman. And when I am *told* of an author of nature who is immense with a threefold boundlessness of intelligence, might, and years; so that to him our great and small, our far and near, our center and circumference — though that circumference sweep around all the expanses of modern astronomy — are practically the same; so that he can properly challenge, "Do not I fill heaven and earth?" — when I am told of this, and I then place myself out under the open dome of nature, amid its exuberant objects and marvelous stretches, I feel myself silently drinking in predispositions to faith as the fleece spread out under the open heaven drinks in the dew. I feel that the doctrine matches facts; that the theory has in its favor a comprehensive verisimilitude and presumption; that Nature, instead of saying, "There is no immense God," significantly asks, in a tone of encouragement and with a look of incipient expectation, "Is there *not* such a Being?" In fine, I feel that our slight lifting of the veil from the painting has disclosed a feature strikingly characteristic of the great master to whom the work is attributed — a feature which, in the absence of all counter-evidence, naturally sets our faces faithward — one, of several harmonies which, as successively presented, will warrant us in looking faithward with evergrowing kindliness of aspect.

Notice with me the *variety in unity* that characterizes Nature.

Some hundreds of millions of creatures on our earth are so much alike that we put them into a class by themselves and call them men. They are all alike in certain fundamental features; and yet each man differs materially, both in body and soul, from every other man. So of every other class of things — animal, vegetable, inorganic; while there is a sub-stratum of unity among the members of each, on account of which they are classed together, there is not one which is not very unlike, in many respects, all its fellows. All animals have great points in common: but how many, many sorts of animals; and how great the difference between the eagle and the microscopic mote, between the cetus and the polyp, between the most perfect man (body and soul) and the rudest of the polypi! All vegetables are similarly constituted: but whose memory can master all the distinct kinds of vegetables in the wide interval between the spire of grass and the huge tree that wrestles victoriously with stormy centuries; and reckon up the great differences that exist, as to shape and size and color and flavor and odor, among fruits and flowers and leaves and grasses and shrubs and trees. Great threads of unity obviously connect all the forms of terrestrial being, organic and inorganic; but this we know, that, if only single specimens of all the plainly

separated species were attempted to be brought together into one Crystal Palace of a museum, we should have to roof in empires, instead of acres, in order to accommodate their mighty array: and as our eye would run over the whole superb collection, and at last bring together the two termini — viz., the material man and the material stone just crumbling into dust — our sense would be that of a miraculous diversity effloresceing out of the unity of our world. So with those other worlds that shine or hide in the vault above. They are all spheres, all have orbitual and probably axial motions, all are governed by the same principle and law of gravitation, all are lighted and colored and warmed by the same mysterious element or impulse; but on such basal unity is superimposed an almost infinite variety. Observe our solar system. One member of it is self-luminous, and, relatively to the other members, a nearly stationary body; the others are dark, and far-wandering planets. One is one hundred miles in diameter, another nearly one hundred thousand, while still another contains more than eight hundred times as much matter as all the remainder of the system can boast. Some have atmospheres and seas, others have neither. Some have moons, others have none. Saturn rides forth in the pomp of three great equatorial rings, as well as of eight moons; no other planet is similarly furnished. These orbs of our system differ

greatly in density — one is as lead, another as cork, another still is mere vapor. One receives seven times as much light from the sun as we, another only a three hundred and sixtieth part of as much. Neptune's year is equal to one hundred and sixty-five of our years. Saturn's day is only one-half of our day. Of course the products and scenery of these worlds, as well as the constitution of their inhabitants, must differ exceedingly. But pass we on to the region of the fixed stars. Have we escaped into immeasurable uniformity out of immeasurable variety? Lo! we skirt systems, clusters, firmaments, and never two alike, while some stand apart by whole universes of difference! Lo, systems with several suns each, from one to a hundred! Lo, systems lighted, some with white suns, some with ruby, some with emerald, and some with suns of many different colors! Lo, suns differing exceedingly in size and amount of light they shed: for the great Sirius that flashes first magnitudes on all our charts as well as on the dazzled retina of the savage, is not as near to us as the little 61 Cygni, and its light must be equal to that of two hundred and fifty suns like our own! Alcyone shines with a force of twelve thousand suns. And then we have suns themselves combined into systems of all sizes and shapes — systems of two, of three, of many, of millions, — firmaments which, un-

der the name of nebulæ, are the last generalization and most stupendous variety of modern discovery: sometimes rolled up into spheres; sometimes gathered into circular or elliptic rings; now fan-shaped; now like an hour-glass; now broad wheels of compacted suns, large, glittering, and sublime enough to under-roll the chariot of immeasurable God. There are not two leaves or grass-blades perfectly alike in all this verdant world; not two worlds, nor systems of worlds, accurately alike in all the prodigious realms of astronomy.

Now no one, to say the least, can claim that this vast variety imbosomed in unity makes positively *against* the idea of one Creator of boundless invention and executive faculty. On the contrary, it is just what we should have *expected* from such a being. Given just such a many-sided, versatile, complete Deity as is affirmed — we should say that, in case he should set himself to produce a vast universe, he would be *likely* to produce one in which great outlines of unity would be steeped in immeasurable variation; one in which resemblance and diversity, both robed and featured like goddesses, would hold each other by the hand and go treading with wedded and festival step up and down the whole quickened area. Nay, this sort of universe one would make *sure* of finding; would be greatly disappointed if he should not find. The eternal laws of his own nature would

demand it of the Great Builder. The invincible beauty and fitness of things would demand it. Perfect uniformity, however piled up in magnificent magnitudes — even a uniformity only varied after so cramped and frugal a fashion as would be perpetually suggesting poverty of resources — would belie the inexhaustible Divinity. If he build at all, he must not misrepresent and disparage himself in his work; his fruitful nature, teeming with all imaginable fertilities and seeds, must surely blossom into very much that marvelous fruitfulness of product and pattern which we observe. And when I am *told* of an author of nature whose being swarms in resistless force toward every point of the compass, nay of the sphere; who is both a unit and a polygon, facing every desideratum and possibility with a flashing side, both of thought and action, that out-dazzles the sun — when I am told that such a being is the author of nature, and I then put myself forth under the open dome amid the glorious diversities that root themselves in the glorious unity of nature, and open myself freely to all their subtle suggestions and magnetisms, I feel myself drinking in predispositions to faith, as the exposed fleece drinks in the dew. I feel that again the doctrine matches facts, that again the theory has a comprehensive verisimilitude and presumption, that Nature instead of saying that there is no God whose unity is arborescent

with endless varieties of beauty and power, significantly asks, "Is there *not* such a Being? In fine, I feel that our continued lifting of the veil from the painting has disclosed a second trait strikingly characteristic of the Great Master to whom the work is attributed; a trait which, added to the first, warrants our faithward look in taking on new kindliness of aspect.

Another characteristic of nature deserving of notice is the *perfection of its details.*

The exquisite finish of nature in its minutest parts is about as wonderful as its vastness and variety. Scan that leaf. Examine the wing of that butterfly. Let the tinted and polished antennæ of that moth glitter in the focus of your instrument. Subject to the skilfullest notice of science and art the smallest veins of any animal or vegetable. Push the analysis just as far as possible, and submit that last visible minimum of organization in the crystalline lens of the cod, with its five millions of muscles and sixty thousand millions of teeth, to the most searching criticism of the superbest microscope. What exquisite details! What elaborate refinement of workmanship! It is not as with some master-piece of human painting — the main points only cared for, while all the subordinate are too rude to bear close inspection. Titian painted this landscape. Well, it is worthy of him — the general effect is beautiful. Yet, if you approach, and closely examine the fo-

liage of the trees, the grass with which the canvas is green, or even the limbs and features of the animals, they will be found very coarsely and incorrectly executed. The microscope turns the most finished work of man into coarseness and clumsiness — indeed, almost immediately carries the sight where traces of skill have totally disappeared. Not so with the works of nature. A real landscape you may analyze to your heart's content, and inspect its details as critically as eye armored with lens can do, without finding the workmanship growing less exquisite the further you push inquiry. A real man — you may descend to the minutest particulars of his organization, and get as near its primary elements as an Ehrenberg with his superb instruments and practiced vision can carry you, without finding the least falling off from that delicacy of execution which appears on the larger masses and outlines of the body. So everywhere among natural objects — the great and the small, the outlines and the minute filling-up, as far as utmost optical resources can carry our observation, are wrought with apparently the same overflowing outlay of attention and skill. It is not so in a few instances merely, nor in a thousand — it is so universally.

That there are any so preposterous as to think that this feature of nature makes positively *against* the idea of a sparrow-watching, hair-numbering, and thought-weighing God is, of course,

not to be imagined. Of course, it is a feature that fully *harmonizes* with such an idea. A nature finished exquisitely down to the most infinitesimal of its details is just what one would have *predicted* from a God of this description. Announced the fact that He was about to create, and expectation would have stood on tiptoe to look for just such a nature as we see. A God for whose vision nothing is too small, who necessarily gives as complete attention to the affairs of an atom as to those of an empire, who can concentrate his almightiness with as much freedom and accuracy on a mathematical point as on a world, who is embarrassed no more by unlimited multiplicity than by unlimited minuteness of details, who can with equal ease paint a landscape on the point of a needle — say, if you please, forty thousand of such landscapes at once, with all their innumerable and minima particulars, back of the reticulated eyes of a single butterfly — can with equal ease do this, and roll a solar system on its triumphant path about the Pleiades; do I not know that a being with such a striking attribute as this would surely give it expression in his works? Do I not know that he who is equally at home in maxima and minima, and to whom beauties and glories in the world of infinitesimals would be just as apparent and practicable as they are in the world of infinites, would lay himself out on the one very much as on the other — would effulge

himself into the microcosmos very much as into the cosmos? When, then, I am *told* that such a being is the author of nature, and I proceed to place myself out under the open dome amid the exquisite elaborations that swarm on every hand down through the veriest miracles of littleness and detail, and to uncover myself candidly to all their subtle whisperings and magnetisms, I feel myself softly drinking in predispositions to faith, as the exposed fleece drinks in the dew, I so feel the force of a doctrine matching facts, and buttressing itself again and again with comprehensive verisimilitudes and presumptions, that to me nature becomes articulate, and, instead of swearing with uplifted hand that there is *no* wondrous God, significantly points upward, and, with bated breath and expectant look, asks, "Is there *not* such a Being?" — in fine, I feel that our continued lifting of the veil from the painting has disclosed another characteristic of the Great Master to whom the work is attributed, the third of those several harmonies which, as successively presented, warrant us in looking faithward with ever-growing kindliness of aspect.

Another feature of Nature is what I shall call its *wisdom.*

The world is full of what, if accepted as the work of an intelligent being, would be called contrivances — adaptations of means to ends — often of the most complex and elaborate description.

For example, the birds — how admirably adapted to flying; in shape, feathers, bones, wings! The fishes — how adapted to swimming and life in the water; witness their shape, their smooth and unctuous scales, their pairs of fins, their tails and gills! The land-animals — how adapted to walking and running and feeding on the earth's surface; to eat the grass or catch their special prey! The trees — how adapted to stand firmly; by their roots, their perpendicularity, their balanced branches, their moderate flexibility — how adapted for shade, for abating the violence of winds, for fuel! Or, if you will consider particular organs of the organic tribes, look at the bark of trees as related to their nourishment, at the web-foot in its double relation to land and water, at the teeth and other preparers of food for the stomach, at the stomach as a preparer of food for the blood, at the lungs as purifiers of the blood, at the heart as the engine for forcing the blood to all parts of the system, at the hand as the general servant of the whole body; in short, at almost any organ of either animal or vegetable structures. The adaptations are wonderful. They are physical miracles — the means are shaped and applied to the ends so exactly, beautifully, triumphantly. For example, no work of human ingenuity that ever you saw is equal to that natural marvel, the human eye — an organ having reference to an element quite external to itself, whose chief source

is millions of leagues distant; and also to millions of external objects which compose our scenery of earth and sky — an organ placed in the most elevated part of the body so as to command the most extensive prospect; placed in the front so as most readily to preside over the direction in which we habitually move; placed in a strong bony socket which defends it from the heavier external injuries; imbedded in a soft cushion, so that its delicate texture can not be hurt by the bony walls around it, as it rests on them, and turns swiftly hither and thither at the bidding of the will; furnished with lids, like curtains, to close over it in sleep, to wipe it, to cut off the outer rays of light that would confuse vision, to protect it by their involuntary and instantaneous shutting against the lighter kind of injuries; furnished with an apparatus of muscles by which it can be rapidly turned at choice in any direction, so as to vary the field of vision as the needs of life may suggest; furnished with a self-acting system of appliances by which the ball is kept lubricated for easy movement; furnished with a conduit to carry off the superfluous moisture; furnished with just that shape, out of ten thousand possible shapes, which mathematicians have demonstrated to be the only one which can refract all the rays of light to a single surface, and thus afford distinct vision, viz., that of an ellipsoid of revolution; furnished with a retina or natural canvas

on which its pictures of external objects can be formed, of just the right size, and at just the right distance behind the lenses of the eye; furnished with lenses of different substances having different refractive powers, thereby preventing the light from being resolved into the prismatic colors, and thus misrepresenting and uniforming objects; furnished in front with a perforated membrane that by self-adjustment adapts it to different degrees of light, also with a system of pulleys and ligaments that at a moment's warning alter its convexity and the relative position of parts so as to adapt it to objects at different distances and, what is more wonderful than all, provided in some inscrutable manner with the means of expressing the mind itself, so that one may look into its crystal depths and see intellectuality and scorn and wrath and love, and almost every spiritual state and action. Now, if this is not an amazing congeries of adaptations, there is and can be nothing amazing. If found to be the work of a human artist, it would be called a perfect marvel of ingenuity and wisdom. And yet some insects have twenty thousand such eyes combined into one. But the eye is only one among an infinity of natural contrivances. Animate and inanimate nature is mountainous and glittering with them. Down into the regions of the infinitely small, whither only the most searching microscopes carry the sight; up into the regions of the infinitely

large and far, whither only mightiest telescopes lift our struggling knowledge; among the mechanisms of the atomic nations that people a single leaf, and among the mechanisms of those swarming celestial empires whose starry banners sweep our nightly skies — it is everywhere the same; exquisite adaptations crowding exquisite adaptations, profound contrivances (so inventors and mechanicians would be tempted to call them) heaped on profound contrivances, in such endless amounts and varieties of wise structure, as exhausts all human understanding and dwarfs into nothingness all the products of human ingenuity.

Does such a nature as this swear *against* a Divine Contriver. Does it protest against him, or testify against him, or breathe even a suspicion against him? Many absurd things are done in the world: but it will be hard to find the man who will care to deny the positive and emphatic *harmony* between the doctrine of an omniscient and omnipotent God and a universe crowded with such splendors of natural mechanics. A God of endless invention, and whose powerful and skilled hands can magnificently realize all that he has magnificently planned — we should *expect* that such a being, in case he should create a nature, would set it all ablaze with the monuments of his supreme intelligence and power — should be *disappointed* to find no such monuments, but, in

their stead, mere stupidity or tameness of work. We should call the work unworthy of the workman. Nay, we should hasten to say to ourselves that we must have mistaken him — He could really be nothing more than such a petty divinity as the poor heathen have fabled to themselves. For we should be sure that one having unlimited command of ways and means, both as a knower and worker, would display it in his works. It being just as easy for him to have exquisite adaptations, and a gloriously endless variety of them, as to have no adaptations at all — it is plain what sort of nature he ought to make and would make. Now let me be *told* of a framer of nature in whom are hid all the treasures of wisdom and knowledge, whose light has in it no darkness at all, whose smallest deeds have from the hoary everlasting been pavilioned and charioted toward being amid the glories of Almighty Omniscience; and I then place myself out under the open dome mid the wilderness of wonderful constructions and chemistries, and candidly uncover myself to all their subtle sympathies and magnetisms — I feel myself, all silently, drinking in predispositions to faith, as the exposed fleece drinks in the dew. I feel that the God who is affirmed is just the God to match the nature which I see — here the ball and there the socket, here the foot Titanic and there its footprint, here the shapely hand and there its glove, here the sover-

eign sword and there the golden scabbard that just fits it — that these noble adaptations and mechanisms, spangling and blazoning all the fields of matter, are in rejoicing sympathy with the idea of a Creator who is wonderful in counsel and excellent in working; that the alabaster-box of precious wisdom that has been emptied, not only on the queenly head and shining tresses of Nature but on her very feet, scents bravely of One who is himself a "mountain of such spikenard;" that, in fact, the theory is again smiled upon by a comprehensive verisimilitude and presumption; that Nature, instead of swearing with uplifted hand that there is no All-wise Creator, with flushed cheek and upward-glancing eye of expectation, significantly asks, "Is there *not* such a Being?" In fine, I feel that our continued lifting of the veil from the painting has disclosed still another characteristic of the Great Master to whom the work is attributed; has cleared up another stretch of that vista at the end of which is Titian at his easel — the fourth of those several harmonies, which, as successively presented, warrant us in looking faithward with ever-growing kindliness of aspect.

Another striking feature of Nature is its *power*.

No contemptible degree of force resides in the muscles of some men — the Samsons and Milos of their time. Huge rocks are lifted, tough oaks are riven, great structures are shaken down by

their hands. Many brute animals display still greater muscular strength; witness the elephant, and those gigantic mammals which towered and ruled over the post-tertiary savannas. A combination of animal forces with what are called the mechanical powers often generates measures of force more striking still; and when men stand by such piles as the Egyptian pyramids, they are deeply impressed with the prodigious uplift that must have put those mighty blocks in their high places. But it is to inanimate nature that we must go for our most brilliant examples of physical force. What power in the wind, when, as a tornado, it sweeps along at more than one hundred miles an hour; demolishing mansions, uprooting forests, and lifting ponderous ships far inland on their eddies! What power in the ocean-swell as it tosses an entire navy to the skies with apparently as much ease as if it were a single cockle-shell! — What is this that comes rushing through the landscape with smoky breath and thunderous step, dragging thousands of tons at the pace of winds? Within that flying iron crater is imprisoned one of nature's brawniest forces, steam — throwing off feats of toil with its vaporous arms, which arms of flesh and blood have never even been fabled to do. — What have we here? A few barrels filled with very simple black grains. One has but to drop a spark among them to witness a sudden development of power that shall

deafen earth and heaven with its voice, and lift a city into mid-air. — Would you see a mightier energy still? It is the year 1755. An unwonted trembling stirs the air and ground of Lisbon. In a few moments the broad city is in heaps. The plain around runs in waves, like the sea when lashed by a tempest. See — the distant mountain-ranges themselves impetuously shake and rend and topple; Europe, to the Highlands of Scotland, heaves; heaves Africa; heaves the whole broad Atlantic, with all its huge gravities, from the Pillars of Hercules to the New World! When oceans and continents are so tossed and shot aloft, what stalwart shoulders of gas and steam and fire are heaving at the mighty burden! Other forces among us are not small; but this of the earthquake is easy king over all these terrestrial children of pride. Terrestrial, I say: but there are forces not terrestrial which are of a still huger and loftier pattern — celestial forces, to which those of our earth are what the bubble-globules of the children are to the globed worlds of space. When such a planet as Jupiter is moving at the rate of some thirty thousand miles an hour; when such a sun as ours is moving at the rate of some three thousand miles a minute; when such a nebula as our Milky Way, with its eighteen millions of suns, goes wheeling at the same average speed about its center of gravity — there is a momentum for you, a magazine

of force by the side of which earthquakes are puny, and all the stormy winds that ever blustered and fought in their fabled caves mere zeros! Some say that there is but one force in all nature — none perhaps more apt to say it than the rejecters of the supernatural — that the forces which pump and assimilate and reject in every blade of grass and leaf and animal fiber; the forces that throb in every ray of light and heat and electricity and magnetism, the forces that swell and toil in every atom of matter, the mechanical forces, the chemical forces, the spiritual forces, the forces here and the forces yonder to the universe's last suburb — that all these forces, with their incomprehensible sum-total of simultaneous impulses, are, after all, but branches of one great central force pushing outward in an infinite variety of directions and forms. If this is so — and who is competent to positively deny it — what a single force that is which can diffuse itself over so immense an area, and divide itself so infinitely, and yet thunder away at special points with such marvelous and terrible energy! If this is not so, still what a wondrous hive of swarming and independent dynamics in this wide nature of ours!

Of course, no one could have the hardihood to say that a nature stocked with such energies as these makes positively *against* the doctrine of a Creator who is himself an Almighty Force. On

the contrary, there is a friendly *harmony* between the doctrine and the fact. Were we to find in actual existence a Personal Power to whom nothing is impossible, and learn that he is about to produce a universe, we should *expect* to see produced just such a wonderfully strong nature as we actually have — a nature peopled with strengths, momenta, brawny agencies of most imposing forms and magnitudes. A weak system, a system that is puny in its operations and trifling in its effects, would misrepresent him — shall I not say, would be unworthy of him? Most persons would certainly call it unsuitable; would say that his very nature as an Infinite Power would *demand* of him that he should produce a system that would be continually turning out the greatest results, and so must include forces of the greatest efficiency. When, then, I am *told* that a Sublime Force, who has Almighty for his name, is the author of nature; and I then proceed to place myself out under the open dome amid the pulsings and tossings of innumerable and sometimes immeasurable momenta, and so lay myself honestly open to all their subtle hints and magnetisms; I feel myself silently drinking in predispositions to faith as the exposed fleece drinks in the dew — I feel that the doctrine matches facts; that the asserted creator and creation fit each other as do the die and the face of the coin which it has stamped; that the theory has at least the bene-

diction of yet another verisimilitude and presumption; that Nature, instead of making oath with serene brow and uplifted hand, that there is no wondrous God, significantly asks, with abashed voice, "Is there *not* such a Being?" — in fine, I feel that, as the veil continues to rise from the face of the painting, it reveals still another characteristic of the Great Master, clears up another stretch of that vista which conducts the sight toward Titian bending over his canvas — the fifth of those several harmonies which, as successively presented, warrant us in looking faithward with ever-growing kindliness of aspect.

Another feature of Nature is its remarkable *relation to law.*

Notice *law and its exceptions* — the general steadfastness of modes of being and action in nature, and the occasional breaches in that steadfastness.

On the earth's surface, in its dark interior, in the air and vault above, in the instant present and the ancient past — everywhere, law waves its mighty scepter. Atoms and masses, the ponderables and inponderables, the organic and inorganic, the living and dead — all are evidently subjected in their modes of being and action to certain fixed rules, sometimes particular, but more often covering whole classes of objects. Not a particle floats at random or as a unit: not a leaf grows or falls save according to rigid gene-

ral principles of science. All chemical elements have their modes and measures of combination to which they steadfastly adhere. All heat, electricity, magnetism, gravity, act according to abiding methods which philosophers have gradually discovered and arranged into the sciences of natural philosophy. The great processes of vegetable and animal life proceed after the same forms and steps, from age to age. The stone beds of the world are formed and modified in certain set ways which are the same now as in the periods anterior to man. Even the weather, so often called fickle, has its stable methods; almost every year bringing to light some new general fact in meteorology, or extending the application of an old one. Day and night succeed each other, every twenty-four hours, without variation. The seasons do not change their order or general character. All of Kepler's and Newton's laws are as operative to-day as they ever have been since their discovery. The planets shoot round the sun and are circled by their own moons, on substantially the same elliptical orbits, in the same times, and with the same principles of alternate retardation and acceleration as of old. All known changes in the planetary orbits have been found to be bound in a law of periodicity which is apparently invariable. So beyond the solar system. Law still; nothing but law; law everywhere on ten thousand blazing thrones; largely the same laws that prevail

in our own system! As far as we can observe — and it is no little that has been observed — those distant orbs reverence the various principles of gravitation and mechanics, and keep as rigidly to their behests, as when the earliest astronomy gazed at them from its rude Uraniberg of a hill-top. And every man of science is well persuaded that, could his observation alight on particular orbs of those remote and twinkling hosts, he would find their minutest details bound up in the chains of the same adamantine regularity that rules our own globe.

So in general we speak. But we must not be understood to speak with absolute precision of language. In this wide scene of steadfast arrangements, there are outbreaks of anomaly — ruptures and rents and dislocations in the habits and ongoings of nature, like those in the strata of the earth. It is a settled law of nature that like shall produce like; yet from perfect animals and vegetables occur occasional monstrosities of organization. It is a settled course of nature that certain substances, called poisons, if freely introduced into animal systems, destroy life; yet now and then a man is found who is even nourished by these agents of destruction. It is a fixed mode of nature that frost withers flat foliage; yet the flat leaves of the wild laurel flourish out our hardest winters. It is a fixed way of nature that the heavenly bodies move in ellipses; yet there

is reason to believe that some comets have been found moving on the curve called a parabola. The steadfast habit of nature is against a general planetary deluge, or conflagration, or glacier-period, or destructive convulsion; yet such disasters, if geology may be trusted, have several times occurred, at immense intervals, in the history of our own planet. Great exceptional events; phenomena without fellows through an astonishing stretch of ages; what have the appearance of broad fractures and dislocations of nature, though in reality they may be the rare resultants and accumulations of innumerable natural forces and laws crossing each other in all directions; the entire destruction and rehabilitation of animal and vegetable species — such events have taken place on this globe again and again. Repeatedly has the earth been drowned and torn in pieces. It has been piled with snow and ice from pole to pole. It has been all ablaze and fused. And is it not on the idea of such a conflagration that we can best account for the new stars that have sometimes flashed suddenly on the sight with all the splendor of Venus at its brightest, and, after a few months of changing color and gradual decay, finally disappeared? Thus in the bosom of a general steadfastness are found occasional outbreaks of anomaly. It is as among the geologic strata — where are found faults, dislocations, fissures, and even reversions of those great rock-

beds which in general are laid down on a plan of utmost regularity. The course of nature is like some great thoroughfare, which advances through great distances without the slightest solution of its continuity, but at last finds a great river thrust squarely across its track. On this side the thoroughfare, on that side the thoroughfare, and here the broad, deep flow of the bridgeless river — a river worth to the public, it may be, many times what the perfect continuity of the road would be.

Now this much is certain. No one can say that this characteristic of nature makes positively *against* such a steadfast and yet miracle-working God as is affirmed in the Christian Scriptures. Instead of opposition, there is positive *harmony* between the fact and the doctrine. Indeed, such a nature as is observed is just what one would have *expected* to come from such a Creator as is taught. Nay, as general laws are necessary to make science possible, to enable men to forecast and profit by experience, to serve as a basis for all comprehensive business and for all civil government — as the broader and profounder the intelligence, the more it is pleased with and tends to work by general principles, we may say that the very nature and circumstances of Deity would *demand* of him, in case he should create, to create a generally steadfast, law-abiding universe. At the same time, a miracle-worker — one who sees a cer-

tain essential imperfection and intractability in second causes, preventing their matching on all occasions the perfection of his ideas; who, moreover, sees it undesirable to allow mere nature to hide its Maker altogether behind its swarming screen, and give to the ideas of necessity and fatality full sweep in human minds — I say, such a being would be under a loud call to provide in the constitution and course of nature such suggestions and prophecies of miracles as would gradually, though perhaps unconsciously to them, prepare the minds of men for those crowning abnormals of the system. He must have the glory of his personal agency glimmer through occasional rents in the uniformity of nature. An anomaly-sprinkled, miracle-suggesting, as well as stable, universe must proceed from his wondrous hand. He would be in conflict with himself were he to produce any other. And when I am *told* of one who is actually just this sort of divinity — both law and miracle: both giver and keeper to an almost infinite extent of moral laws which shall not pass away; while his iron will, throned as supremely in the realm of matter as of morals, yet launches forth into special providences and miracles on extraordinary occasions — when I am told of him, and I then place myself out under the open dome amid the massive but occasionally rifted uniformities, and open myself freely to all

their subtle hints and magnetisms, I feel myself softly drinking in predispositions to faith, as the exposed fleece drinks in the dew. I feel that the doctrine and the facts are at one; that the asserted Creator and the observed creation fit each other as do the signet and the seal just stamped; that another verisimilitude spreads blessing, if tremulous, hand over the theory; that Nature instead of sonorously swearing that there is no Divine Being whose double name is Law and Miracle, significantly asks, with abashed and startled tones, "Is there *not* such a Being?" In fine, I feel that, as the veil continues to rise from the face of the painting, it reveals still another characteristic of the Great Master, clears up another stretch of that vista which conducts the sight toward Titian bending over his canvas — the sixth of those several harmonies which, as successively presented, warrant us in looking faithward with ever-growing kindliness of aspect.

Another feature of Nature is its wonderful *relation to time and motion.*

How long has our race existed? The infidel may choose to say a hundred thousand years; none will say less than six thousand. How long has the earth itself existed? The atheist may choose to say, Forever. The geologist, thinking of his coal beds and deltas and rocky strata sown with the bones of extinct species, and of the time requisite for their formation, is sure of several

hundred thousand years. How long are the earth and its confederates in the solar system calculated to endure? Geometry declares that no element of decay within endangers the stability of the system of the world. That year which circumscribes our seasons is only three hundred and sixty-five days; but the earth has another year to which this is a mere point — its pole goes nodding through space in a circle which it takes twenty-five thousand years to traverse. What think you of a planet whose winter is more than forty of our years, of a comet whose year is more than thirty of our centuries, of a sun whose year is more than eighteen thousand of our millenniums? All the planetary orbits pass through cycles of changes varying in length from a few centuries to nine thousand, to seventy thousand, to even many million years; but the greatest of these planetary cycles are as nothing compared with those enormous periods which bound the perturbations and express the secular equations of the sun and fixed stars — periods including more years than imagination has ever succeeded in realizing to itself. What amazing longevities! What portentous numerals! They are hieroglyphics of the everlasting. They lift us among the dizziest peaks of the sublime.

These immense periods, interspersed with others exceedingly small, sometimes express an exceedingly slow movement among the powers of nature.

In other cases, the movement with which they are connected is exceedingly rapid. The times consumed in the formation of the coal-beds and rock-strata, and in the long perturbations of the planetary and stellar orbits, are examples of the first class of periods; the years of the planets and stars in their orbits are examples of the second. In the first class, natural forces creep along to their objects with miraculous slowness; in the other, they flash along with swiftness equally astounding. Some orbits gradually lengthen themselves, say an inch in a thousand years. Some of the stars dart along their year of one hundred and eighty thousand centuries at the incomprehensible rate of one hundred and eighty thousand miles an hour. Could we plant ourselves immovably at a certain point in the celestial spaces, and see our sun go sailing by with all its glorious squadrons of planets and moons — sailing down the abyss as if driven by ten thousand hurricanes — would not the sight of such celerity almost irrecoverably daze both senses and spirit?

If, now, one should start up to say that these great cycles, imbosoming unutterable extremes of movement, makes positively *against* an Eternal God who is able to move to his purpose like the light or at a rate so trifling as to be quite imperceptible by human senses, we should laugh his logic to scorn. We know better. These are facts

that palpably *agree* with such a theism. Instead of contradicting it, they express a state of things that might have been *expected* from a being who has both unlimited time and unlimited speed at his disposal — who, if he chooses to wait, has never occasion to haste; or, if he chooses to haste, has never occasion to wait — who is alike able to dart on his purpose as if infinite whirlwinds were in his wings, or to approach it at a rate so minute that no human sense can discern the movement in the lapse of generations. Suppose such a God to be about to create a nature, could you not confidently predict after this manner — "This Being of mighty periods will establish mighty periods: this Being who can readily proceed on his endlessly varied designs, at all imaginable and unimaginable rates of speed, will diversify his works with all the velocities." A God who himself has no duration to speak of — if there may be such a God — would never have stored his nature with such mighty cycles; a God who himself never did a swift thing would never have set his laws to spurring on planets and suns so astoundingly; a God who himself never did a slow thing would never have yoked such slow-footed forces to events, as we observe actually dragging at some of them. It is only a God who has substantial forevers on his hands, and who on occasion can lighten and on occasion can linger ineffably along the highway of his purposes, who is properly represented by such a nature. In case

he gives any nature at all, his character demands of him to give just this — one expressing his own attributes. So when I am *told* of one whose longevity is eternity, whose orbit of existence has an infinite axis, who reaches an Atonement after slowly beating toward it for forty centuries, who is ages and dispensations in establishing his kingdom in the world, who commonly approaches the punishment of sinners with steps lingering through numberless delays and forbearances, and who yet sometimes yokes steeds of wind and fire and foam to his car — as when some Korah and his company go down quick into the pit; or some Uzziah, profanely grasping an ark, falls dead; or some Ananias and Sapphira, lying to the Holy Ghost, are rushed to judgment in an instant's brief space — when I am told of such a God creating nature; and I then betake myself abroad under the open dome amid those swarming and wondrous orbits of time, now scarred and smoking with the hot hoofs of electric forces, and now pressed by the velvety and trackless feet of forces born of the snail; and frankly lay myself open to all their subtle hints and magnetisms — I feel myself silently drinking in faith, as the exposed fleece drinks in the dew — I feel that there is a significant matching of what we are taught with what we observe; that such theism is on most excellent and embracing terms with Nature, which, so far from saying with uplifted, oath-making hand, 'that

there is no Eternal God who, as an agent, is equally at home in an instant and an age,' at least stands tremulously querying, "Is there *not* such a Being?"— in fine, I feel that, as the veil continues to rise from the face of the painting, it reveals still another characteristic of the Great Master, clears up another stretch of that vista which conducts the sight on Titian painting away sublimely at his glowing and glorified landscape — the seventh of those several harmonies which, as successively presented, warrant us in looking faithward with ever-growing kindliness of aspect.

Another feature — the *mysteriousness* of Nature.

Who does not know it? — terrestrial nature is one huge sphinx. She vomits enigmas on us in seas. Riddles too profound for the highest science yet in our possession lurk in every ray of light, in every blade of grass, in every rudest stone. Only some of the coarser facts in relatian to a few things here and there, have been picked up and systematized; and these are what compose our boasted sciences. From surface to center, the earth is choked with mysteries whose stony rind has never yet received a blow, much less a fracture, from the mallet of investigation. Come now, ye great Computers, compute for us how long it will be before the science, which loses itself at the very threshold of the complexities of this world, will be able to swoop down with

triumphant wing upon the surfaces and to the fiery centers of those fellow planets that mysteriously weave and interweave paths across the concave, and thoroughly solve the problem of all their swarming contents! A disorderly maze are the apparent paths of the members of our solar system! But you say that the real paths are not as intricate as the apparent. Take your stand, then, at the sun, and observe planets and comets going and coming at all distances and rates of velocity and directions; while around most of the larger planets are similarly moving, other systems of satellites — is it not an intricate as well as a brave sight? Can you see through the mazy plan? But you say that it has been seen through, and planetariums have been made that clearly represent the whole thing to us within a few feet of space. How many centuries and philosophers, O Copernicus — Copernicus, I say, away yonder in the depths of four hundred years ago — did it take to make that orrery and solve that riddle of the system of the world? Indeed, it is yet very far from solution. Astronomers can only completely account for the movements of a system of two bodies. A system of three is quite beyond them; one of a hundred and more bodies, like our solar system, immeasurably beyond them. There is not even a hope that science, with all its dynamical calculuses, will ever overtake this higher problem. But

there is a higher problem still. Solar system revolves around solar system; a group of such systems around a similar group; a cluster of such groups around a similar cluster; a firmament of such clusters around a similar firmament. Indeed, as we have seen, the whole universe of stars, with all the countless fleets of planets and moons which they represent, must, according to the law of gravity, revolve about a last center of centers. Let us go to it. Standing at this Heaven — for is not this the dazzling metropolis where dwells the sublime Cesar of the creation — standing at this wondrous point, and looking forth on the countless nebulæ coming and going at all imaginable distances, speeds, and directions — lo, what a glorious scene of bewilderment and unsearchable complexity! It fairly takes away our breath to look. There is no more spirit left in us. If a system of three bodies is too much for the most subtle and comprehensive science yet known, what can ever be done by all coming generations and geniuses, however imperial, toward mastering such labyrinthian immensity of involved orbs?

Now hearken to the Christian Scriptures — affirming a Maker of nature who is himself the mightiest of all enigmas. "Verily, thou art a God that hidest thyself — Canst thou by searching find out God; canst thou find out the Almighty to perfection — It is high as heaven; what canst

thou do: deep as hell; what canst thou know?" Does the aspect of nature contradict this doctrine? Who will presume to deny that the incomprehensible materialism about us, to say nothing of the more incomprehensible spiritualism within us, is just what one would expect to find issuing from the hands of an incomprehensible Creator — a being mysteriously without a beginning, mysteriously self-existent, mysteriously able to make the greatest and noblest things out of nothing by simple volition, mysteriously all-knowing, mysteriously unfettered in the application of his power and knowledge by all conditions of space and duration and personal presence, mysteriously Three in One — in short, a being enveloped in a terrible pomp and majesty of sunset-clouds, whose broken lines never permit the orb that glorifies them to appear, even for a moment, in clear and golden contour on our rapt sight. Such a being, setting out to create, would be *likely* to give us the present enigmatic universe, nay — for why state the matter so feebly — would be *sure* to give it. Like every other copious author, he would reproduce his own traits. An unutterable sphinx himself, his creatures would be sphinxes. A nature from the hands of God that I can comprehend, or make any approach to comprehending — preposterous! A creation that to me, with my low place and filmy vision and narrow orbit, is not

steeped in seas of mystery — preposterous! If a Jehovah build the temple of nature at all, he will found it on mysteries, frame it with mysteries, cover and dome it with mysteries, pillar and ballast it with mysteries, pave and ceil it with a mosaic of mysteries — surely he will. And when I am *told* of a being whose own nature is an overwhelming problem; whose attributes have no horizon, no zenith, and no nadir; whose ends respect all possible objects and interests, and spread themselves out in plans of boundless vastness whose merest corners and differentials only are visible to men of the widest scope: when I am told of him, and I then place myself out under nature's open dome, amid its Protean inscrutableness of leaf and star, of whole crowded earth and circumventing heavens — the peopled heavens where sweep in inextricable maze the hurricane hosts of advancing and retreating orbs; and open my soul candidly to all their silent suggestions and magnetisms — I feel myself drinking in faith, as the fleece spread out under the stars drinks in the dew — I feel that the facts give embracing arms to the doctrine; that the actual universe, instead of swearing with decisive voice and hand uplift to heaven that there is no inscrutable God, significantly asks with panting whisper and color that comes and goes, "Is there *not* such a Being?" In fine, I feel that our continued lifting of the veil from the painting has disclosed another char-

acteristic of the great master to whom the work is attributed; has cleared up another stretch of that vista which conducts the sight to Titian in the act of glorifying his canvas into the Milanese Coronation-Christ — another of those many harmonies which, as successively presented, warrant us in looking faithward with ever-growing kindliness of aspect.