# The Mathematical Principles of Natural Philosophy

Isaac Newton

## Dedication

TO THE TEACHERS OF THE NORMAL SCHOOL OF THE STATE OF NEW-YORK.

Gentlemen:—

A stirring freshness in the air, and ruddy streaks upon the horizon of the moral world betoken the grateful dawning of a new era. The days of a drivelling instruction are departing. With us is the opening promise of a better time, wherein genuine manhood doing its noblest work shall have adequate reward. Teacher is the highest and most responsible office man can fill. Its dignity is, and will yet be held commensurate with its duty—a duty boundless as man's intellectual capacity, and great as his moral need—a duty from the performance of which shall emanate an influence not limited to the *now* and the *here*, but which surely will, as time flows into eternity and space into infinity, roll up, a measureless curse or a measureless blessing, in inconceivable swellings along the infinite curve. It is an office that should be esteemed of even sacred import in this country. Ere long a hundred millions, extending from the Atlantic to the Pacific, from Baffin's Bay to that of Panama, shall call themselves American citizens. What a field for those two master-passions of the human soul—the love of Rule, and the love of Gain! How shall our liberties continue to be preserved from the graspings of Ambition and the corruptions of Gold? Not by Bills of Rights Constitutions, and Statute Books; but alone by the rightly cultivated hearts and heads of the People. They must themselves guard the Ark. It is yours to fit them for the consecrated charge. Look well to it: for you appear clothed in the majesty of great power! It is yours to fashion, and to inform, to save, and to perpetuate. You are the Educators of the People: you are the prime Conservators of the public weal. Betray your trust, and the sacred fires would go out, and the altars crumble into dust: knowledge become lost in tradition, and Christian nobleness a fable! As you, therefore, are multiplied in number, elevated in consideration, increased in means, and fulfill, well and faithfully, all the requirements of true Teachers, so shall our favoured land lift up her head among the nations of the earth, and call herself blessed.

In conclusion, Gentlemen, to you, as the conspicuous leaders in the vast and honourable labour of Educational Reform, and Popular Teaching, the First American Edition of the Principia of Newton—the greatest work of the greatest Teacher—is most respectfully dedicated.

N. W. CHITTENDEN. (Editor)

# Introduction To The American Edition

That the Principia of Newton should have remained so generally unknown in this country to the present day is a somewhat remarkable fact; because the name of the author, learned with the very elements of science, is revered at every hearth-stone where knowledge and virtue are of chief esteem, while, abroad, in all the high places of the land, the character which that name recalls is held up as the noblest illustration of what Man may be, and may do, in the possession and manifestation of pre-eminent intellectual and moral worth; because the work is celebrated, not only in the history of one career and one mind, but in the history of all achievement and human reason itself; because of the spirit of inquiry, which has been aroused, and which, in pursuing its searchings, is not always satisfied with stopping short of the fountain-head of any given truth; and, finally, because of the earnest endeavour that has been and is constantly going on, in many sections of the Republic, to elevate the popular standard of education and give to scientific and other efforts a higher and a better aim.

True, the Principia has been hitherto inaccessible to popular use. A few copies in Latin, and occasionally one in English may be found in some of our larger libraries, or in the possession of some ardent disciple of the great Master. But a dead language in the one case, and an enormous price in both, particularly in that of the English edition, have thus far opposed very sufficient obstacles to the wide circulation of the work. It is now, however, placed within the reach of all. And in performing this labour, the utmost care has been taken, by collation, revision, and otherwise, to render the First American Edition the most accurate and beautiful in our language. "Le plus beau monument que l'on puisse élever à la gloire de Newton, c'est une bonne édition de ses ouvrages:" and a monument like unto that we would here set up. The Principia, above all, glows with the immortality of a transcendant mind. Marble and brass dissolve and pass away; but the true creations of genius endure, in time and beyond time, forever: high upon the adamant of the indestructible, they send forth afar and near, over the troublous waters of life, a pure, unwavering, quenchless light whereby the myriad myriads of barques, richly laden with reason, intelligence and various faculty, are guided through the night and the storm, by the beetling shore and the hidden rock, the breaker and the shoal, safely into havens calm and secure.

To the teacher and the taught, the scholar and the student, the devotee of Science and the worshipper of Truth, the Principia must ever continue to be of inestimable value. If to educate means, not so much to store the memory with symbols and facts, as to bring forth the faculties of the soul and develope them to the full by healthy nurture and a hardy discipline, then, what so effective to the accomplishment of that end as the study of Geometrical Synthesis? The Calculus, in some shape or other, is, indeed, necessary to the successful prosecution of researches in the higher branches of philosophy. But has not the Analytical encroached upon the Synthetical, and Algorithmic Formulae been employed when not requisite, either for the evolution of truth, or even its apter illustration? To each method belongs, undoubtedly, an appropriate use. Newton, himself the inventor of Fluxions, censured the handling of Geometrical subjects by Algebraical calculations; and the maturest opinions which he expressed were additionally in favour of the Geometrical Method. His preference, so strongly marked, is not to be reckoned a mere matter of taste; and his authority should bear with preponderating weight upon the decision of every instructor in adopting what may be deemed the best plan to insure the completest mental development. Geometry, the vigorous product of remote time; blended with the earliest aspirations of Science and the earliest applications of Art; as well in the measures of music as in the movement of spheres; as wholly in the structure of the atom as in that of the world; directing Motion and shaping Appearance; in a word, at the moulding of the created all, is, in comprehensive view, the outward form of that Inner Harmony of which and in which all things are. Plainly, therefore, this noble study has other and infinitely higher uses than to increase the power of abstraction. A more general and thorough cultivation of it should be strenuously insisted on. Passing from the pages of Euclid or Legendre, might not the student be led, at the suitable time, to those of the Principia wherein Geometry may be found in varied use from the familiar to the sublime? The profoundest and the happiest results, it is believed, would attend upon this enlargement of our Educational System.

Let the Principia, then, be gladly welcomed into every Hall where a true teacher presides. And they who are guided to the diligent study of this incomparable work, who become strengthened by its reason, assured by its evidence, and enlightened by its truths, and who rise into loving communion with the great and pure spirit of its author, will go forth from the scenes of their pupilage, and take their places in the world as strong-minded, right-hearted men—such men as the Theory of our Government contemplates and its practical operation absolutely demands.

# Life Of Sir Isaac Newton

From the thick darkness of the middle ages man's struggling spirit emerged as in new birth; breaking out of the iron control of that period; growing strong and confident in the tug and din of succeeding conflict and revolution, it bounded forwards and upwards with resistless vigour to the investigation of physical and moral truth; ascending height after height; sweeping afar over the earth, penetrating afar up into the heavens; increasing in endeavour, enlarging in endowment; every where boldly, earnestly out-stretching, till, in the Author of the Principia, one arose, who, grasping the master-key of the universe and treading its celestial paths, opened up to the human intellect the stupendous realities of the material world, and, in the unrolling of its harmonies, gave to the human heart a new song to the goodness, wisdom, and majesty of the all-creating, all-sustaining, all-perfect God.

Sir Isaac Newton, in whom the rising intellect seemed to attain, as it were, to its culminating point, was born on the 25th of December, O. S. 1642—Christmas day—at Woolsthorpe, in the parish of Colsterworth, in Lincolnshire. His father, John Newton, died at the age of thirty-six, and only a few months after his marriage to Harriet Ayscough, daughter of James Ayscough, of Rutlandshire. Mrs. Newton, probably wrought upon by the early loss of her husband, gave premature birth to her only and posthumous child, of which, too, from its extreme diminutiveness, she appeared likely to be soon bereft. Happily, it was otherwise decreed! The tiny infant, on whose little lips the breath of life so doubtingly hovered, lived;—lived to a vigorous maturity, to a hale old age;—lived to become the boast of his country, the wonder of his time, and the "ornament of his species."

Beyond the grandfather, Robert Newton, the descent of Sir Isaac cannot with certainty be traced. Two traditions were held in the family: one, that they were of Scotch extraction; the other, that they came originally from Newton, in Lancashire, dwelling, for a time, however, at Westby, county of Lincoln, before the removal to and purchase of Woolsthorpe—about a hundred years before this memorable birth.

The widow Newton was left with the simple means of a comfortable subsistence. The Woolsthorpe estate together with small one which she possessed at Sewstern, in Leicestershire, yielded her an income of some eighty pounds; and upon this limited sum, she had to rely chiefly for the support of herself, and the education of her child. She continued his nurture for three years, when, marrying again, she confided the tender charge to the care of her own mother.

Great genius is seldom marked by precocious development; and young Isaac, sent, at the usual age, to two day schools at Skillington and Stoke, exhibited no unusual traits of character. In his twelfth year, he was placed at the public school at Grantham, and boarded at the house of Mr. Clark, an apothecary. But even in this excellent seminary, his mental acquisitions continued for a while unpromising enough: study apparently had no charms for him; he was very inattentive, and ranked low in the school. One day, however, the boy immediately above our seemingly dull student gave him a severe kick in the stomach; Isaac, deeply affected, but with no outburst of passion, betook himself, with quiet, incessant toil, to his books; he quickly passed above the offending classmate; yet there he stopped not; the strong spirit was, for once and forever, awakened, and, yielding to its noble impulse, he speedily took up his position at the head of all.

His peculiar character began now rapidly to unfold itself. Close application grew to be habitual. Observation alternated with reflection. "A sober, silent, thinking lad," yet, the wisest and the kindliest, the indisputable leader of his fellows. Generosity, modesty, and a love of truth distinguished him then as ever afterwards. He did not often join his classmates in play; but he would contrive for them various amusements of a scientific kind. Paper kites he introduced; carefully determining their best form and proportions, and the position and number of points whereby to attach the string. He also invented paper lanterns; these served ordinarily to guide the way to school in winter mornings, but occasionally for quite another purpose; they were attached to the tails of kites in a dark night, to the dismay of the country people dreading portentous comets, and to the immeasureable delight of his companions. To him, however, young as he was, life seemed to have become an earnest thing. When not occupied with his studies, his mind would be engrossed with mechanical contrivances; now imitating, now inventing. He became singularly skilful in the use of his little saws, hatchets, hammers, and other tools. A windmill was erected near Grantham; during the operations of the workmen, he was frequently present; in a short time, he had completed a perfect working model of it, which elicited general admiration. Not content, however, with this exact imitation, he conceived the idea of employing, in the place of sails, animal power, and, adapting the construction of his mill accordingly, he enclosed in it a mouse, called the miller, and which by acting on a sort of treadwheel, gave motion to the machine. He invented, too, a mechanical carriage—having four wheels, and put in motion with a handle worked by the person sitting inside. The measurement of time early drew his attention. He first constructed a water clock, in proportions somewhat like an old-fashioned house clock. The index of the dial plate was turned by a piece of wood acted upon by dropping water. This instrument, though long used by himself, and by Mr. Clark's family, did not satisfy his inquiring mind. His thoughts rose to the sun; and, by careful and oft-repeated observations of the solar movements, he subsequently formed many dials. One of these, named *Isaac's dial*, was the accurate result of years' labour, and was frequently referred to for the hour of the day by the country people.

May we not discern in these continual efforts—the diligent research, the patient meditation, the aspiring glance, and the energy of discovery—the stirring elements of that wondrous spirit, which, clear, calm, and great, moved, in after years, through deep onward through deep of Nature's mysteries, unlocking her strongholds, dispelling darkness, educing order—everywhere silently conquering.

Newton had an early and decided taste for drawing. Pictures, taken sometimes from copies, but often from life, and drawn, coloured and framed by himself, ornamented his apartment. He was skilled also, in poetical composition, "excelled in making verses;" some of these were borne in remembrance and repeated, seventy years afterward, by Mrs. Vincent, for whom, in early youth, as Miss Storey, he formed an ardent attachment. She was the sister of a physician resident near Woolsthorpe; but Newton's intimate acquaintance with her began at Grantham, where they were both numbered among the inmates of the same house. Two or three years younger than himself, of great personal beauty, and unusual talent, her society afforded him the greatest pleasure; and their youthful friendship, it is believed, gradually rose to a higher passion; but inadequacy of fortune prevented their union. Miss Storey was afterwards twice married; Newton, never; his esteem for her continued unabated during life, accompanied by numerous acts of attention and kindness.

In 1656, Newton's mother was again left a widow, and took up her abode once more at Woolsthorpe. He was now fifteen years of age, and had made great progress in his studies; but she, desirous of his help, and from motives of economy, recalled him from school. Business occupations, however, and the management of the farm, proved utterly distasteful to him. When sent to Grantham Market on Saturdays, he would betake himself to his former lodgings in the apothecary's garret, where some of Mr. Clark's old books employed his thoughts till the aged and trustworthy servant had executed the family commissions and announced the necessity of return: or, at other times, our young philosopher would seat himself under a hedge, by the wayside, and continue his studies till the same faithful personage—proceeding alone to the town and completing the day's business—stopped as he returned. The more immediate affairs of the farm received no better attention. In fact, his passion for study grew daily more absorbing, and his dislike for every other occupation more intense. His mother, therefore, wisely resolved to give him all the advantages which an education could confer. He was sent back to Grantham school, where he remained for some months in busy preparation for his academical studies. At the recommendation of one of his uncles, who had himself studied at Trinity College, Cambridge, Newton proceeded thither, and was duly admitted, on the 5th day of June 1660, in the eighteenth year of his age.

The eager student had now entered upon a new and wider field; and we find him devoting himself to the pursuit of knowledge with amazing ardour and perseverance. Among other subjects, his attention was soon drawn to that of Judicial Astrology. He exposed the folly of this pseudo-science by erecting a figure with the aid of one or two of the problems of Euclid; — and thus began his study of the Mathematics. His researches into this science were prosecuted with unparallelled vigour and success. Regarding the propositions contained in Euclid as self-evident truths, he passed rapidly over this ancient system — a step which he afterward much regretted — and mastered, without further preparatory study, the Analytical Geometry of Descartes. Wallis's Arithmetic of Infinites, Saunderson's Logic, and the Optics of Kepler, he also studied with great care; writing upon them many comments; and, in these notes on Wallis's work was undoubtedly the germ of his fluxionary calculus. His progress was so great that he found himself more profoundly versed than his tutor in many branches of learning. Yet his acquisitions were not gotten with the rapidity of intuition; but they were thoroughly made and firmly secured. Quickness of apprehension, or intellectual nimbleness did not belong to him. He saw too far: his insight was too deep. He dwelt fully, cautiously upon the least subject; while to the consideration of the greatest, he brought a massive strength joined with a matchless clearness, that, regardless of the merely trivial or unimportant, bore with unerring sagacity upon the prominences of the subject, and, grappling with its difficulties, rarely failed to surmount them.

His early and last friend, Dr. Barrow—in compass of invention only inferior to Newton—who had been elected Professor of Greek in the University, in 1660, was made Lucasian Professor of Mathematics in 1663, and soon afterward delivered his Optical Lectures: the manuscripts of these were revised by Newton, and several oversights corrected, and many important suggestions made by him; but they were not published till 1669.

In the year 1665, he received the degree of Bachelor of Arts; and, in 1666, he entered upon those brilliant and imposing discoveries which have conferred inappreciable benefits upon science, and immortality upon his own name.

Newton, himself, states that he was in possession of his Method of Fluxions, "in the year 1666, or before." Infinite quantities had long been a subject of profound investigation; among the ancients by Archimedes, and Pappus of Alexandria; among the moderns by Kepler, Cavaleri, Roberval, Fermat and Wallis. With consummate ability Dr. Wallis had improved upon the labours of his predecessors: with a higher power, Newton moved forwards from where Wallis stopped. Our author first invented his celebratedBinomial Theorem. And then, applying this

Theorem to the rectification of curves, and to the determination of the surfaces and contents of solids, and the position of their centres of gravity, he discovered the general principle of deducing the areas of curves from the ordinate, by considering the area as a nascent quantity, increasing by continual fluxion in the proportion of the length of the ordinate, and supposing the abscissa to increase uniformly in proportion to the time. Regarding lines as generated by the motion of points, surfaces by the motion of lines, and solids by the motion of surfaces, and considering that the ordinates, abscissae, &c., of curves thus formed, vary according to a regular law depending on the equation of the curve, he deduced from this equation the velocities with which these quantities are generated, and obtained by the rules of infinite series, the ultimate value required. To the velocities with which every line or quantity is generated, he gave the name of Fluxions, and to the lines or quantities themselves, that of Fluents. A discovery that successively baffled the acutest and strongest intellects: — that, variously modified, has proved of incalculable service in aiding to develope the most abstruse and the highest truths in Mathematics and Astronomy: and that was of itself enough to render any name illustrious in the crowded Annals of Science.

At this period, the most distinguished philosophers were directing all their energies to the subject of light and the improvement of the refracting telescope. Newton, having applied himself to the grinding of "optic glasses of other figures than spherical," experienced the impracticability of executing such lenses; and conjectured that their defects, and consequently those of refracting telescopes, might arise from some other cause than the imperfect convergency of rays to a single point. He accordingly "procured a triangular glass prism to try therewith the celebrated phenomena of colours." His experiments, entered upon with zeal, and conducted with that industry, accuracy, and patient thought, for which he was so remarkable, resulted in the grand conclusion, that Light was not homogeneous, but consisted of rays, some of which were more refrangible than others. This profound and beautiful discovery opened up a new era in the History of Optics. As bearing, however, directly upon the construction of telescopes, he saw that a lens refracting exactly like a prism would necessarily bring the different rays to different foci, at different distances from the glass, confusing and rendering the vision indistinct. Taking for granted that all bodies produced spectra of equal length, he dismissed all further consideration of the refracting instrument, and took up the principle of reflection. Rays of all colours, he found, were reflected regularly, so that the angle of reflection was equal to the angle of incidence, and hence he concluded that *optical instruments might be brought to any degree of perfection imaginable*, provided reflecting specula of the requisite figure and finish could be obtained. At this stage of his optical researches, he was forced to leave Cambridge on account of the plague which was then desolating England.

He retired to Woolsthorpe. The old manor-house, in which he was born, was situated in a beautiful little valley, on the west side of the river Witham; and here in the quiet home of his boyhood, he passed his days in serene contemplation, while the stalking pestilence was hurrying its tens of thousands into undistinguishable graves.

Towards the close of a pleasant day in the early autumn of 1666, he was seated alone beneath a tree, in his garden, absorbed in meditation. He was a slight young man; in the twenty-fourth year of his age; his countenance mild and full of thought. For a century previous, the science of Astronomy had advanced with rapid strides. The human mind had risen from the gloom and bondage of the middle ages, in unparalleled vigour, to unfold the system, to investigate the phenomena, and to establish the laws of the heavenly bodies. Copernicus, Tycho Brahe, Kepler, Galileo, and others had prepared and lighted the way for him who was to give to their labour its just value, and to their genius its true lustre. At his bidding isolated facts were to take order as parts of one harmonious whole, and sagacious conjectures grow luminous in the certain splendour of demonstrated truth. And this ablest man had come—was here. His mind, familiar with the knowledge of past effort, and its unequalled faculties developed in transcendant strength, was now moving on to the very threshold of its grandest achievement. Step by step the untrodden path was measured, till, at length, the entrance seemed disclosed, and the tireless explorer to stand amid the first opening wonders of the universe.

The nature of gravity—that mysterious power which causes all bodies to descend towards the centre of the earth—had, indeed, dawned upon him. And reason busily united link to link of that chain which was yet to be traced joining the least to the vastest, the most remote to the nearest, in one harmonious bond. From the bottoms of the deepest caverns to the summits of the highest mountains, this power suffers no sensible change: may not its action, then, extend to the moon? Undoubtedly: and further reflection convinced him that such a power might be sufficient for retaining that luminary in her orbit round the earth. But, though this power suffers no sensible variation, in the little change of distance from the earth's centre, at which we may place ourselves, yet, at the distance of the moon, may not its force undergo more or less diminution? The conjecture appeared most probable: and, in order to estimate what the degree of diminution might be, he considered that if the moon be retained in her orbit by the force of gravity, the primary planets must also be carried round the sun by the like power; and, by comparing the periods of the several planets with their distances from the sun, he found that, if they were held in their courses by any power like gravity, its strength must decrease in the duplicate proportion of the in crease of distance. In forming this conclusion, he supposed the planets to move in perfect circles, concentric to the sun. Now was this the law of the moon's motion? Was such a force, emanating from the earth and directed to the moon, sufficient, when diminished as the square of the distance, to retain her in her orbit? To ascertain this master-fact, he compared the space through which heavy bodies fall, in a second of time, at a given distance from the centre of the earth, namely, at its surface, with the space through which the moon falls, as it were, to the earth, in the same time, while revolving in a circular orbit. He was absent from books; and, therefore, adopted, in computing the earth's diameter, the common estimate of sixty miles to a degree of latitude as then in use among geographers and navigators. The result of his calculations did not, of course, answer his expectations; hence, he concluded that some other cause, beyond the reach of observation—analogous, perhaps, to the vortices of Descartes—joined its action to that of the power of gravity upon the moon. Though by no means satisfied, he yet abandoned awhile further inquiry, and remained totally silent upon the subject.

These rapid marches in the career of discovery, combined with the youth of Newton, seem to evince a penetration the most lively, and an invention the most exuberant. But in him there was a conjunction of influences as extraordinary as fortunate. Study, unbroken, persevering and profound carried on its informing and disciplining work upon a genius, natively the greatest, and rendered freest in its movements, and clearest in its vision, through the untrammelling and enlightening power of religion. And, in this happy concurrence, are to be sought the elements of those amazing abilities, which, grasping, with equal facility, the minute and the stupendous, brought these successively to light, and caused science to make them her own.

In 1667, Newton was made a Junior Fellow; and, in the year following, he took his degree of Master of Arts, and was appointed to a Senior Fellowship.

On his return to Cambridge, in 1668, he resumed his optical labours. Having thought of a delicate method of polishing metal, he proceeded to the construction of his newly projected reflecting telescope; a small specimen of which he actually made with his own hands. It was six inches long; and magnified about forty times;—a power greater than a refracting instrument of six feet tube could exert with distinctness. Jupiter, with his four satellites, and the horns, or moon-like phases of Venus were plainly visible through it. This was the first reflecting telescope ever executed and directed to the heavens. He gave an account of it, in a letter to a friend, dated February 23d, 1668-9—a letter which is also remarkable for containing the first allusion to his discoveries "concerning the nature of light." Encouraged by the success of his first experiment, he again executed with his own hands, not long afterward, a second and superior instrument of the same kind. The existence of this having come to the knowledge of the Royal Society of London, in 1671, they requested it of Newton for examination. He accordingly sent it to them. It excited great admiration; it was shown to the king; a drawing and description of it was sent to Paris; and the telescope itself was carefully preserved in the Library of the Society. Newton lived to see his invention in public use, and of eminent service in the cause of science.

In the spring of 1669, he wrote to his friend Francis Aston, Esq., then about setting out on his travels, a letter of advice and directions, it was dated May 18th, and is interesting as exhibiting some of the prominent features in Newton's character. Thus:—

"Since in your letter you give me so much liberty of spending my judgment about what may be to your advantage in travelling, I shall do it more freely than perhaps otherwise would have been decent. First, then, I will lay down some general rules, most ofwhich, I believe, you have considered already; but if any of them be new to you, they may excuse the rest; if none at all, yet is my punishment more in writing than yours in reading.

"When you come into any fresh company. 1. Observe their humours. 2. Suit your own carriage thereto, by which insinuation you will make their converse more free and open. 3. Let your discourse be more in queries and doubtings than peremptory assertions or disputings, it being the design of travellers to learn, not to teach. Besides, it will persuade your acquaintance that you have the greater esteem of them, and so make them more ready to communicate what they know to you; whereas nothing sooner occasions disrespect and quarrels than peremptoriness. You will find little or no advantage in seeming wiser or much more ignorant than your company. 4. Seldom discommend any thing though never so bad, or do it but moderately, lest you be unexpectedly forced to an unhandsome retraction. It is safer to commend any thing more than it deserves, than to discommend a thing so much as it deserves; for commendations meet not so often with oppositions, or, at least, are not usually so ill resented by men that think otherwise, as discommendations; and you will insinuate into men's favour by nothing sooner than seeming to approve and commend what they like; but beware of doing it by comparison. 5. If you be affronted, it is better, in a foreign country, to pass it by in silence, and with a jest, though with some dishonour, than to endeavour revenge; for, in the first case, your credit's ne'er the worse when you return into England, or come into other company that have not heard of the quarrel. But, in the second case, you may bear the marks of the quarrel while you live, if you outlive it at all. But, if you find yourself unavoidably engaged, 'tis best, I think, if you can command your passion and language, to keep them pretty evenly at some certain moderate pitch, not much heightening them to exasperate your adversary, or provoke his friends, nor letting them grow overmuch dejected to make him insult. In a word, if you can keep reason above passion, that and watchfulness will be your best defendants. To which purpose you may consider, that, though such excuses as this—He provok't me so much I could not forbear—may pass among friends, yet amongst strangers they are insignificant, and only argue a traveller's weakness.

"To these I may add some general heads for inquiries or observations, such as at present I can think on. As, 1. To observe the policies, wealth, and state affairs of nations, so far as a solitary traveller may conveniently do. 2. Their impositions upon all sorts of people, trades, or commodities, that are remarkable. 3. Their laws and customs, how far they differ from ours. 4. Their trades and arts wherein they excel or come short of us in England. 5. Such fortifications as you shall meet with, their fashion, strength, and advantages for defence, and other such military affairs as are considerable, 6. The power and respect be longing to their degrees of nobility or magistracy. 7. It will not be time misspent to make a catalogue of the names and excellencies of those men that are most wise, learned, or esteemed in any nation. 8. Observe the mechanism and manner of guiding ships. 9. Observe the products of Nature in several places, especially in mines, with the circumstances of mining and of extracting metals or minerals out of their ore, and of refining them; and if you meet with any transmutations out of their own species into another (as out of iron into copper, out of any metal into quick silver, out of one salt into another, or into an insipid body, &c.), those, above all, will be worth your noting, being the most luciferous, and many times lucriferous experiments, too, in philosophy. 10. The prices of diet and other things. 11. And the staple commodities of places.

"These generals (such as at present I could think of), if they will serve for nothing else, yet they may assist you in drawing up a model to regulate your travels by. As for particulars, these that follow are all that I can now think of, viz.; whether at Schemnitium, in Hungary (where there are mines of gold, copper, iron, vitriol, antimony, &c.). they change iron into copper by dissolving it in a vitriolate water, which they find in cavities of rocks in the mines, and then melting the slimy solution in a strong fire, which in the cooling proves copper. The like is said to be done in other places, which I cannot now remember; perhaps, too, it may be done in Italy. For about twenty or thirty years agone there was a certain vitriol came from thence (called Roman vitriol), but of a nobler virtue than that which is now called by that name; which vitriol is not now to be gotten, because, perhaps, they make a greater gain by some such trick as turning iron into copper with it than by selling it. 2. Whether, in Hungary, Sclavonia, Bohemia, near the town Eila, or at the mountains of Bohemia near Silesia, there be rivers whose waters are impregnated with gold; perhaps, the gold being dissolved by some corrosive water like *aqua regis*, and the solution carried along with the stream, that runs through the mines. And whether the practice of laying mercury in the rivers, till it be tinged with gold, and then straining the mercury through leather, that the gold may stay behind, be a secret yet, or openly practised. 3. There is newly contrived, in Holland, a mill to grind glasses plane withal, and I think polishing them too; perhaps it will be worth the while to see it. 4. There is in Holland one—Borry, who some years since was imprisoned by the Pope, to have extorted from him secrets (as I am told) of great worth, both as to medicine and profit, but he escaped into Holland, where they have granted him a guard. I think he usually goes clothed in green. Pray inquire what you can of him, and whether his ingenuity be any profit to the Dutch. You may inform yourself whether the Dutch have any tricks to keep their ships from being all worm-eaten in their voyages to the Indies. Whether pendulum clocks do any service in finding out the longitude, &c.

"I am very weary, and shall not stay to part with a long compliment, only I wish you a good journey, and God be with you."

It was not till the month of June, 1669, that our author made known his Method of Fluxions. He then communicated the work which he had composed upon the subject, and entitled, Analysis per Equationes numero terminorum Infinitas, to his friend Dr. Barrow. The latter, in a letter dated 20th of the same month, mentioned it to Mr. Collins, and transmitted it to him, on the 31st of July thereafter. Mr. Collins greatly approved of the work; took a copy of it; and sent the original back to Dr. Barrow. During the same and the two following years, Mr. Collins, by his extensive correspondence, spread the knowledge of this discovery among the mathematicians in England, Scotland, France, Holland and Italy.

Dr. Barrow, having resolved to devote himself to Theology, resigned the Lucasian Professorship of Mathematics, in 1669, in favour of Newton, who accordingly received the appointment to the vacant chair.

During the years 1669, 1670, and 1671, our author, as such Professor, delivered a course of Optical Lectures. Though these contained his principal discoveries relative to the different refrangibility of light, yet the discoveries themselves did not be come publicly known, it seems, till he communicated them to the Royal Society, a few weeks after being elected a member thereof, in the spring of 1671-2. He now rose rapidly in reputation, and was soon regarded as foremost among the philosophers of the age. His paper on light excited the deepest interest in the Royal Society, who manifested an anxious solicitude to secure the author from the "arrogations of others," and proposed to publish his discourse in the monthly numbers in which the Transactions were given to the world. Newton, gratefully sensible of these expressions of esteem, willingly accepted of the proposal for publication. He gave them also, at this time, the results of some further experiments in the decomposition and re-composition of light:—that the same degree of refrangibility always belonged to the same colour, and the same colour to the same degree of refrangibility: that the seven different colours of the spectrum were original, or simple, and that *whiteness*, or white light was a compound of all these seven colours.

The publication of his new doctrines on light soon called forth violent opposition as to their soundness. Hooke and Huygens—men eminent for ability arid learning—were the most conspicuous of the assailants. And though Newton effectually silenced all his adversaries, yet he felt the triumph of little gain in comparison with the loss his tranquillity had sustained. He subsequently remarked in allusion to this controversy—and to one with whom he was destined to have a longer and a bitterer conflict—"I was so persecuted with discussions arising from the publication of my theory of light, that I blamed my own imprudence for parting with so substantial a blessing as my quiet to run after a shadow.

In a communication to Mr. Oldenburg, Secretary of the Royal Society, in 1672, our author stated many valuable suggestions relative to the construction of Reflecting

Microscopes which he considered even more capable of improvement than telescopes. He also contemplated, about the same time, an edition of Kinckhuysen's Algebra, with notes and additions; partially arranging, as an introduction to the work, a treatise, entitled, A Method of Fluxions; but he finally abandoned the design. This treatise, however, he resolved, or rather consented, at a late period of his life, to put forth separately; and the plan would probably have been carried into execution had not his death intervened. It was translated into English, and published in 1736 by John Colson, Professor of Mathematics in Cambridge.

Newton, it is thought, made his discoveries concerning the Inflection and Diffraction of light before 1674. The phenomena of the inflection of light had been first discovered more than ten years before by Grimaldi. And Newton began by repeating one of the experiments of the learned Jesuit—admitting a beam of the sun's light through a small pin hole into a dark chamber: the light diverged from the aperture in the form of cone, and the shadows of all bodies placed in this light were larger than might have been expected, and surrounded with three coloured fringes, the nearest being widest, and the most remote the narrowest. Newton, advancing upon this experiment, took exact measures of the diameter of the shadow of a human hair, and of the breadth of the fringes, at different distances behind it, and discovered that these diameters and breadths were not proportional to the distances at which they were measured. He hence supposed that the rays which passed by the edge of the hair were deflected or turned aside from it, as if by a repulsive force, the nearest rays suffering the greatest, the more remote a less degree of deflection. In explanation of the coloured fringes, he queried: whether the rays which differ in refrangibility do not differ also in flexibility, and whether they are not, by these different inflections, separated from one another, so as after separation to make the colours in the three fringes above described? Also, whether the rays, in passing by the edges and sides of bodies, are not bent several times backwards and forwards with an eel-like motion—the three fringes arising from three such bendings? His inquiries on this subject were here interrupted and never renewed.

His Theory of the Colours of Natural Bodies was communicated to the Royal Society, in February, 1675. This is justly regarded as one of the profoundest of his speculations. The fundamental principles of the Theory in brief, are:—That bodies possessing the greatest refractive powers reflect the greatest quantity of light; and that, at the confines of equally refracting media, there is no reflection. That the minutest particles of almost all natural bodies are in some degree transparent. That between the particles of bodies there are pores, or spaces, either empty or filled with media of a less density than the particles themselves. That these particles, and pores or spaces, have some definite size. Hence he deduced the Transparency, Opacity, and colours of natural bodies. Transparency arises from the particles and their pores being too small to cause reflection at their common surfaces—the light all passing through; Opacity from the opposite cause of the particles and their pores being sufficiently large to reflect the light which is "stopped or stifled" by the multitude of reflections; and colours from the particles, according to their several sizes, reflecting rays of one colour and transmitting those of another—or in other words, the colour that meets the eye is the colour reflected, while all the other rays are transmitted or absorbed.

Analogous in origin to the colours of natural bodies, he considered the colours of thin plates. This subject was interesting and important, and had attracted considerable investigation. He, however, was the first to determine the law of the production of these colours, and, during the same year made known the results of his researches herein to the Royal Society. His mode of procedure in these experiments was simple and curious. He placed a double convex lens of a large known radius of curvature, upon the flat surface of a plano-convex object glass. Thus, from their point of contact at the centre, to the circumference of the lens, he obtained plates of air, or spaces varying from the extremest possible thinness, by slow degrees, to a considerable thickness. Letting the light fall, every different thickness of this plate of air gave different colours—the point of contact of the lens and glass forming the centre of numerous concentric colored rings. Now the radius of curvature of the lens being known, the thickness of the plate of air, at any given point, or where any particular colour appeared, could be exactly determined. Carefully noting, therefore, the order in which the different colours appeared, he measured, with the nicest accuracy, the different thicknesses at which the most luminous parts of the rings were produced, whether the medium were air, water, or mica—all these substances giving the same colours at different thicknesses;—the ratio of which he also ascertained. From the phenomena observed in these experiments, Newton deduced his Theory of Fits of Easy Reflection and Transmission of light. It consists in supposing that every particle of light, from its first discharge from a luminous body, possesses, at equally distant intervals, dispositions to be reflected from, or transmitted through the surfaces of bodies upon which it may fall. For instance, if the rays are in a Fit of Easy Reflection, they are on reaching the surface, repelled, thrown off, or reflected from it; if, in a Fit of Easy Transmission, they are attracted, drawn in, or transmitted through it. By this Theory of Fits, our author likewise explained the colours of thick plates.

He regarded light as consisting of small material particles emitted from shining substances. He thought that these particles could be re-combined into solid matter, so that "gross bodies and light were convertible into one another;" that the particles of light and the particles of solid bodies acted mutually upon each other; those of light agitating and heating those of solid bodies, and the latter attracting and repelling the former. Newton was the first to suggest the idea of the Polarization of light.

In the paper entitled *An Hypothesis Explaining Properties of Light*, December, 1675, our author first introduced his opinions respecting Ether—opinions which he afterward abandoned and again permanently resumed—"A most subtle spirit which pervades" all bodies, and is expanded through all the heavens. It is electric, and almost, if not quite immeasurably elastic and rare. "By the force and action of which spirit the particles of bodies mutually attract one another, at near distances, and cohere, if contiguous; and electric bodies operate at greater distances, as well repelling as attracting the neighbouring corpuscles; and light is emitted, reflected, refracted, inflected and heats bodies; and all sensation is excited, and the members of animal bodies move at the command of the will, namely, by the vibrations of this spirit, mutually propagated along the solid filaments of the nerves, from the outward organs of sense to the brain, and from the brain into the muscles." This "spirit" was no *anima mundi*; nothing further from the thought of Newton; but was it not, on his part, a partial recognition of, or attempt to reach an ultimate material force, or primary element, by means of which, "in the roaring loom of time," this material universe, God's visible garment, may be woven for us?

The Royal Society were greatly interested in the results of some experiments, which our author had, at the same time, communicated to them relative to the excitation of electricity in glass; and they, after several attempts and further direction from him, succeeded in re-producing the same phenomena.

One of the most curious of Newton's minor inquiries related to the connexion between the refractive powers and chemical composition of bodies. He found on comparing the refractive powers and the densities of many different substances, that the former were very nearly proportional to the latter, in the same bodies. Unctuous and sulphureous bodies were noticed as remarkable exceptions—as well as the *diamond*—their refractive powers being two or three times greater in respect of their densities than in the case of other substances, while, as among themselves, the one was generally proportional to the other. He hence inferred as to the diamond a great degree of combustibility;—a conjecture which the experiments of modern chemistry have shown to be true.

The chemical researches of our author were probably pursued with more or less diligence from the time of his witnessing some of the practical operations in that science at the Apothecary's at Grantham. De Natura Acidorum is a short chemical paper, on various topics, and published in Dr. Horsley's Edition of his works. Tabula Quantitatum et Graduum Coloris was inserted in the Philosophical Transactions; it contains a comparative scale of temperature from that of melting ice to that of a small kitchen coal-fire. He regarded fire as a body heated so hot as to emit light copiously; and flame as a vapour, fume, or exhalation heated so hot as to shine. To elective attraction, by the operation of which the small particles of bodies, as he conceived, act upon one another, at distances so minute as to escape observation, he ascribed all the various chemical phenomena of precipitation, combination, solution, and crystallization, and the mechanical phenomena of cohesion and capillary attraction. Newton's chemical views were illustrated and confirmed, in part, at least, in his own life-time. As to the structure of bodies, he was of opinion "that the smallest particles of matter may cohere by the strongest attractions, and compose bigger particles of weaker virtue; and many of these may cohere and compose bigger particles whose virtue is still weaker; and so on for divers successions, until the progression end in the biggest particles, on which the operations in chemistry and the colours of natural bodies depend, and which by adhering, compose bodies of sensible magnitude."

There is good reason to suppose that our author was a diligent student of the writings of Jacob Behmen; and that in conjunction with a relative, Dr. Newton, he was busily engaged, for several months in the earlier part of life, in quest of the philosopher's tincture. "Great Alchymist," however, very imperfectly describes the character of Behmen, whose researches into things material and things spiritual, things human and things divine, afford the strongest evidence of a great and original mind.

More appropriately here, perhaps, than elsewhere, may be given Newton's account of some curious experiments, made in his own person, on the action of light upon the retina. Locke, who was an intimate friend of our author, wrote to him for his opinion on a certain fact stated in Boyle's Book of Colours. Newton, in his reply, dated June 30th, 1691, narrates the following circumstances, which probably took place in the course of his optical researches. Thus:—

"The observation you mention in Mr. Boyle's Book of Colours I once tried upon myself with the hazard of my eyes. The manner was this; I looked a very little while upon the sun in the looking-glass with my right eye, and then turned my eyes into a dark corner of my chamber, and winked, to observe the impression made, and the circles of colours which encompassed it, and how they decayed by degrees, and at last vanished. This I repeated a second and a third time. At the third time, when the phantasm of light and colours about it were almost vanished, in tending my fancy upon them to see their last appearance, I found, to my amazement, that they began to return, and by little and little to become as lively and vivid as when I had newly looked upon the sun. But when I ceased to intend my fancy upon them, they vanished again. After this, I found, that as often as I went into the dark, and intended my mind upon them, as when a man looks earnestly to see anything which is difficult to be seen; I could make the phantasm return without looking any more upon the sun; and the oftener I made it return, the more easily I could make it return again. And, at length, by repeating this, without looking any more upon the sun, I made such an impression on my eye, that, if I looked upon the clouds, or a book, or any bright object, I saw upon it a round bright spot of light like the sun, and, which is still stranger, though I looked upon the sun with my right eye only, and not with my left, yet my fancy began to make an impression upon my left eye, as well us upon my right. For if I shut my right eye, or looked upon a book, or the clouds, with my left eye, I could see the spectrum of the sun almost as plain as with my right eye, if I did but intend my fancy a little while upon it; for at first, if I shut my right eye, and looked with my left, the spectrum of the sun did not appear till I intended my fancy upon it; but by repeating, this appeared every time more easily. And now, in a few hours time, I had brought my eyes to such a pass, that I could look upon no blight object with either eye, but I saw the sun before me, so that I durst neither write nor read; but to recover the use of my eyes, shut myself up in my chamber made dark, for three days together, and used all means to divert my imagination from the sun. For if I thought upon him, I presently saw his picture, though I was in the dark. But by keeping in the dark, and employing my mind about other things, I began in three or four days to have some use of my eyes again; and by forbearing to look upon bright objects, recovered them pretty well, though not so well but that, for some months after, the spectrum of the sun began to return as often as I began to meditate upon the phenomena, even though I lay in bed at midnight with my curtains drawn. But now I have been very well for many years, though I am apt to think, if I durst venture my eyes, I could still make the phantasm return by the power of my fancy. This story I tell you, to let you understand, that in the observation related by Mr. Boyle, the man's fancy probably concurred with the impression made by the sun's light to produce that phantasm of the sun which he constantly saw in bright objects. And so your question about the cause of phantasm involves another about the power of fancy, which I must confess is too hard a knot for me to untie. To place this effect in a constant motion is hard, because the sun ought then to appear perpetually. It seems rather to consist in a disposition of the sensorium to move the imagination strongly, and to be easily moved, both by the imagination and by the light, as often as bright objects are looked upon."

Though Newton had continued silent, yet his thoughts were by no means inactive upon the vast subject of the planetary motions. The idea of Universal Gravitation, first caught sight of, so to speak, in the garden at Woolsthorpe, years ago, had gradually expanded upon him. We find him, in a letter to Dr. Hooke, Secretary of the Royal Society, dated in November, 1679, proposing to verify the motion of the earth by direct experiment, namely, by the observation of the path pursued by a body falling from a considerable height. He had concluded that the path would be spiral; but Dr. Hooke maintained that it would be an eccentric ellipse in vacuo, and an ellipti-spiral in a resisting medium. Our author, aided by this correction of his error, and by the discovery that a projectile would move in an elliptical orbit when under the influence of a force varying inversely as the square of the distance, was led to discover "the theorem by which he afterwards examined the ellipsis;" and to demonstrate the celebrated proposition that a planet acted upon by an attractive force varying inversely as the squares of the distances will describe an elliptical orbit, in one of whose foci the attractive force resides.

When he was attending a meeting of the Royal Society, in June 1682, the conversation fell upon the subject of the measurement of a degree of the meridian, executed by M. Picard, a French Astronomer, in 1679. Newton took a memorandum of the result; and afterward, at the earliest opportunity, computed from it the diameter of the earth: furnished with these new data, he resumed his calculation of 1666. As he proceeded therein, he saw that his early expectations were now likely to be realized: the thick rushing, stupendous results overpowered him; he became unable to carry on the process of calculation, and intrusted its completion to one of his friends. The discoverer had, indeed, grasped the master-fact, The law of falling bodies at the earth's surface was at length identified with that which guided the moon in her orbit. And so his Great Thought, that had for sixteen years loomed up in dim, gigantic outline, amid the first dawn of a plausible hypothesis, now stood forth, radiant and not less grand, in the mid-day light of demonstrated truth.

It were difficult, nay impossible to imagine, even, the influence of a result like this upon a mind like Newton's. It was as if the keystone had been fitted to the glorious arch by which his spirit should ascend to the outskirts of infinite space—spanning the immeasurable—weighing the imponderable—computing the incalculable—mapping out the marchings of the planets, and the far-wanderings of the corners, and catching, bring back to earth some clearer notes of that higher melody which, as a sounding voice, bears perpetual witness to the design and omnipotence of a creating Deity.

Newton, extending the law thus obtained, composed a series of about twelve propositions on the motion of the primary planets about the sun. These were sent to London, and communicated to the Royal Society about the end of 1683. At or near this period, other philosophers, as Sir Christopher Wren, Dr. Halley, and Dr. Hooke, were engaged in investigating the same subject; but with no definite or satisfactory results. Dr. Halley, having seen, it is presumed, our author's propositions, went in August, 1684, to Cambridge to consult with him upon the subject. Newton assured him that he had brought the demonstration to perfection. In November, Dr. Halley received a copy of the work; and, in the following month, announced it to the Royal Society, with the author's promise to have it entered upon their Register. Newton, subsequently reminded by the Society of his promise, proceeded in the diligent preparation of the work, and, though suffering an interruption of six weeks, transmitted the manuscript of the first book to London before the end of April. The work was entitled Philosophiæ Naturalis Principia Mathematica, dedicated to the Royal Society, and presented thereto on the 28th of April, 1685-6. The highest encomiums were passed upon it; and the council resolved, on the 19th of May, to print it at the expense of the Society, and under the direction of Dr. Halley. The latter, a few days afterward, communicated these steps to Newton, who, in a reply, dated the 20th of June, holds the following language:—"The proof you sent me I like very well. I designed the whole to consist of three books; the second was finished last summer, being short, and only wants transcribing, and drawing the cuts fairly. Some new propositions I have since thought on, which I can as well let alone. The third wants the theory of comets. In autumn last, I spent two months in calculation to no purpose for want of a good method, which made me afterward return to the first book, and enlarge it with diverse propositions, some relating to comets, others to other things found out last winter. The third I now design to suppress. Philosophy is such an impertinently litigious lady, that a man had as good be engaged in law-suits as have to do with her, I found it so formerly, and now I can no sooner come near her again, but she gives me warning. The first two books without the third will not so well bear the title of *Philosophiæ Naturalis Principia Mathematicia*; and thereupon I had altered it to this, *De Motu Corporum Libri duo*. But after second thought I retain the former title. It will help the sale of the book, which I ought not to diminish now 'tis yours."

This "warning" arose from some pretensions put forth by Dr. Hooke. And though Newton gave a minute and positive refutations of such claims, yet, to reconcile all differences, he generously added to Prop. IV. Cor. 6, Book I., a Scholium, in which Wren, Hooke and Halley are acknowledged to have independently deduced the law of gravity from the second law of Kepler.

The suppression of the third book Dr. Halley could not endure to see. "I must again beg you" says he, "not to let your resentments run so high as to deprive us of your third book, where in your applications of your mathematical doctrine to the theory of comets, and several curious experiments, which, as I guess by what you write ought to compose it, will undoubtedly render it acceptable to those who will call themselves philosophers without mathematics, which are much the greater number," To these solicitations Newton yielded. There were no "resentments," however, as we conceive, in his "design to suppress." He sought peace; for he loved and valued it above all applause. But, in spite of his efforts for tranquillity's sake, his course of discovery was all along molested by ignorance or presumptuous rivalry.

The publication of the great work now went rapidly forwards, The second book was sent to the Society, and presented on the 2d March; the third, on the 6th April; and the whole was completed and published in the month of May, 1686-7. In the second Lemma of the second book, the fundamental principle of his fluxionary calculus was, for the first time, given to the world; but its algorithm or notation did not appear till published in the second volume of Dr. Wallis's works, in 1693.

And thus was ushered into existence The Principia—a work to which pre-eminence above all the productions of the human intellect has been awarded—a work that must be esteemed of priceless worth so long as Science has a votary, or a single worshipper be left to kneel at the altar of Truth.

The entire work bears the general title of The Mathematical Principles Of Natural Philosophy. It consists of three books: the first two, entitled, Of The Motion Of Bodies, are occupied with the laws and conditions of motions and forces, and are illustrated with many scholia treating of some of the most general and best established points in philosophy, such as the density and resistance of bodies, spaces void of matter, and the motion of sound and light. From these principles, there is deduced, in the third book, drawn up in as popular a style as possible and entitled, Of the System of the World, the constitution of the system of the world. In regard to this book, the author says—"I had, indeed, composed the third Book in a popular method, that it might be read by many; but afterwards, considering that such as had not sufficently entered into the principles could not easily discover the strength of the consequences, nor lay aside the prejudices to which they had been many years accustomed, therefore, to prevent disputes which might be raised upon such accounts, I chose to reduce the substance of this Book into the form of Propositions (in the mathematical way), which should be read by those only who had first made themselves masters of the principles established in the preceding Books: not that I would advise any one to the previous study of every Proposition of those Books."—"It is enough it one carefully reads the Definitions, the Laws of Motion, and the three first Sections of the first Book. He may then pass on to this Book, and consult such of the remaining Propositions of the first two Books, as the references in this, and his occasions shall require." So that "The System of the World" is composed both "in a popular method," and in the form of mathematical Propositions.

The principle of Universal Gravitation, namely, *that every particle of matter is attracted by, or gravitates to, every other particle of matter, with a force inversely proportional to the squares of their distances*—is the discovery which characterizes The Principia. This principle the author deduced from the motion of the moon, and the three laws of Kepler—laws, which Newton, in turn, by his greater law, demonstrated to be true.

From the first law of Kepler, namely, the proportionality of the areas to the times of their description, our author inferred that the force which retained the planet in its orbit was always directed to the sun; and from the second, namely, that every planet moves in an ellipse with the sun in one of its foci, he drew the more general inference that the force by which the planet moves round that focus varies inversely as the square of its distance therefrom: and he demonstrated that a planet acted upon by such a force could not move in any other curve than a conic section; showing when the moving body would describe a circular, an elliptical, a parabolic, or hyperbolic orbit. He demonstrated, too, that this force, or attracting, gravitating power resided in every, the least particle; but that, in spherical masses, it operated as if confined to their centres; so that, one sphere or body will act upon another sphere or body, with a force directly proportional to the quantity of matter, and inversely as the square of the distance between their centres; and that their velocities of mutual approach will be in the inverse ratio of their quantities of matter. Thus he grandly outlined the Universal Law. Verifying its truth by the motions of terrestrial bodies, then by those of the moon and other secondary orbs, he finally embraced, in one mighty generalization, the entire Solar System—all the movements of all its bodies—planets, satellites and comets —explaining and harmonizing the many diverse and theretofore inexplicable phenomena.

Guided by the genius of Newton, we see sphere bound to sphere, body to body, particle to particle, atom to mass, the minutest part to the stupendous whole—each to each, each to all, and all to each—in the mysterious bonds of a ceaseless, reciprocal influence. An influence whose workings are shown to be alike present in the globular dew-drop, or oblate-spheroidal earth; in the falling shower, or vast heaving ocean tides; in the flying thistle-down, or fixed, ponderous rock; in the swinging pendulum, or time-measuring sun; in the varying and unequal moon, or earth's slowly retrograding poles; in the uncertain meteor, or blazing comet wheeling swiftly away on its remote, yet determined round. An influence, in fine, that may link system to system through all the star-glowing firmament; then firmament to firmament aye, firmament to firmament, again and again, till, converging home, it may be, to some ineffable centre, where more presently dwells He who