

NATIONAL SECULAR SOCIETY

THE INFLUENCE OF

ASTRONOMICAL DISCOVERY

IN THE

DEVELOPMENT OF THE HUMAN MIND

A Lecture

DELIVERED BEFORE THE

SUNDAY LECTURE SOCIETY,

ON

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BY A. ELLEY FINCH.

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## SYLLABUS.

Earliest notions respecting the Stars. Genesis. Socrates.

Astronomy as Science is the result of mental calculation based on exact observation of the Heavenly Bodies, by aid of the Telescope and other modern scientific instruments.

The Human Understanding previously to the growth of Astronomical Science was under the dominion of the Imagination.

Illustration of the pre-scientific type of mind—Plato.

The conception of the size and nature of the World was imaginary. Illustration from their description by Cosmas.

The destiny of the Universe, and man's position in it were also imaginary. Illustration from the works of the Fathers and Schoolmen.

Sketch of the true System of the World as made known through the great Astronomical Discoveries. Hipparchus (160 A.C.)—Ptolemy (140 A.D.)—Copernicus (1542)—Invention of the Telescope (1609)—Kepler (1619)—Galileo (1632)—Sir Isaac Newton (1687)—Lagrange and Laplace (1776—1825)—Adams (1846), and others.

Astronomical Discovery has displaced the theological scheme of existence by the substitution of a scientific platform; correcting, enlarging, and elevating men's views by transferring the intellectual position of the observer from the Earth to the Sun.

In demonstrating the stability of our Solar System it has destroyed the theological dogma of the approaching end of the World, with all its demoralizing influences.

It reveals the Universe as a realm of Law, and Laws of Nature as Laws of Reason.

It proves a Reign of Reason to be paramount the Dominion of the Imagination. Illustration from astronomical measurements, magnitudes, and distances beyond the realization of the Imagination.

It exhibits the reason of man as part of the universal reason, and both as correlated with a material basis. Illustration from the discovery and connection of Conic Sections, the curvature of the Planetary Orbits, and the Law of Gravitation.

It unfolds an Order of Nature as the criterion of Truth, the area of Knowledge, and the standard of Proportion.

In displaying a real power of Prediction, it has rescued Science from Theology and Metaphysics.

It has sapped Superstition, *i.e.*, Belief inconsistent with the unbiassed dictates of Reason and the verified course of Nature.

In encouraging a love of inquiry in the spirit of Truth, it has invigorated Culture and reformed Education.

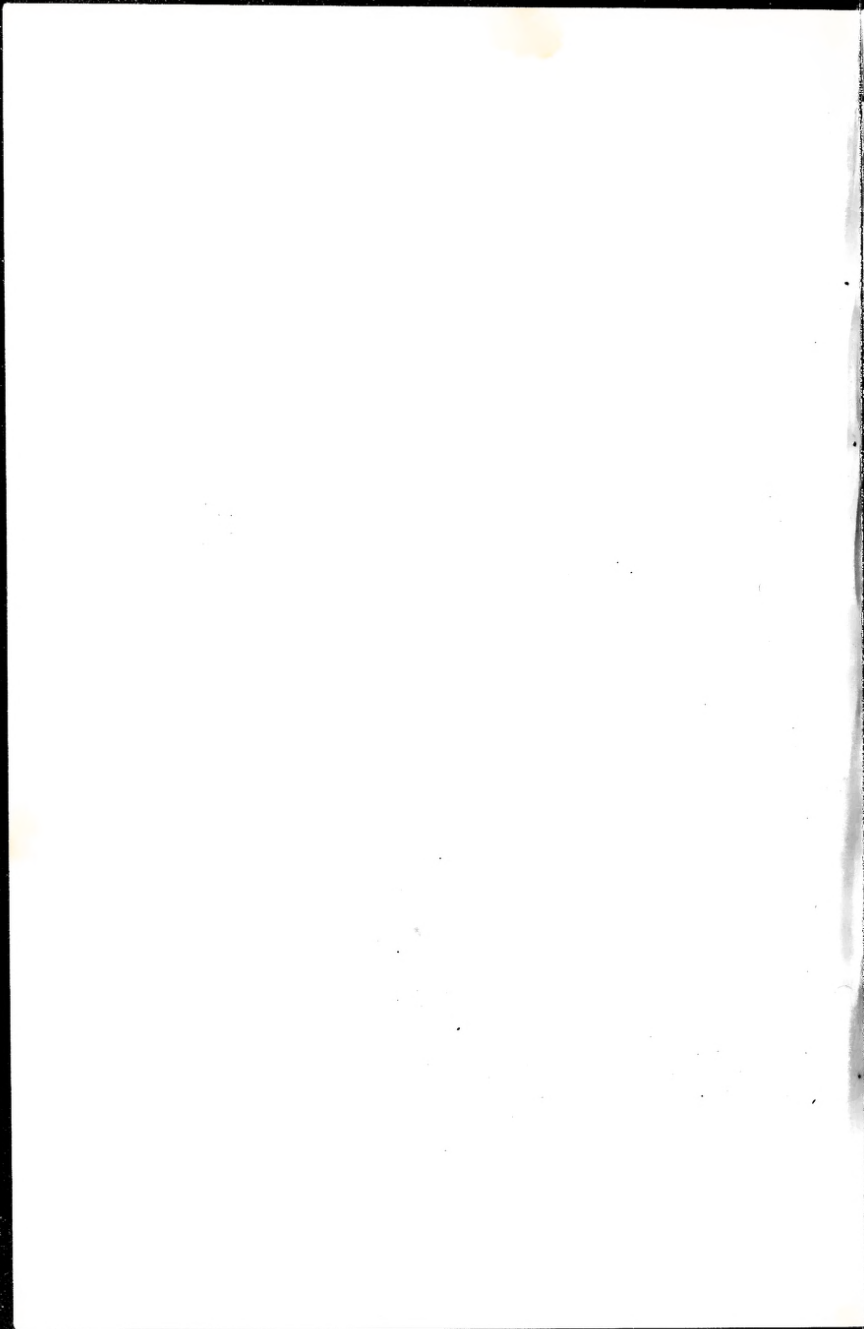
In eradicating vicious views and false beliefs, it has purified Moral Principles and augmented Human Happiness.

Illustration of the scientific type of mind—J. S. Mill.

Plato and Mill—a parallel.

### ILLUSTRATIVE DIAGRAMS.

1. Conic Sections.—2. The Orbit of a Planet round the Sun.—3. Phases of the Planet Venus as shown by the Telescope.—4. Our Solar System.



# THE INFLUENCE OF ASTRONOMICAL DISCOVERY

IN THE

## DEVELOPMENT OF THE HUMAN MIND.

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**T**HE earliest astronomical sentiments of the human race find their simplest expression in our familiar nursery rhyme, dating back probably to those primeval times when, in the cloudless serenity of an oriental night, Shepherd-priests of the Chaldean plains, awe-subdued and silent, intently watch the star-studded expanse, glittering so mysteriously above and around them—

“Twinkle, twinkle little Star,  
How I wonder what you are !”

That the stars were very small bodies, that they could never be more to man than objects of wonder, were the intellectual beliefs of ages—even in the time of the cultured Greeks, we find the great Athenian Socrates pronouncing Astronomy (that science which now exhibits the highest perfection, and most exact power of prediction to which the human mind has ever attained) to be a Divine mystery, impossible to understand, and impious to investigate ; whilst their illustrious Philosopher, Anaxagoras, was accused of blasphemy, for daring to dispersonify their Sun-God Helios, in attempting to assign invariable laws to the Solar phenomena !

But a writer, more ancient than Socrates, perhaps no less illustrious than the Grecian Sage, has ventured to narrate to us, as a fact, the Creation of the little Stars. Thus, he writes—“And God made two great Lights . . . He made the Stars also. And God set them in the firmament of the heaven to give light upon the earth.” Those twinkling points of light are thus regarded as

some small addition to the Sun and Moon, without the least suspicion that each one of their glorious host was itself a mighty Sun, in comparison with whose bulk that of our earth shrinks to insignificance !

Now, one of the most certain, as well as important, of the discoveries of modern Critical Research, has shown us that the Pentateuch is the composition of several writers, put together out of different sources, prior documents or legends ; and it may, I trust, be said without improperly shocking the prejudices of any intelligent person, that the statement I have cited from the book of Genesis, as to the inferior size, and apparent purpose of the Stars, is entirely contradicted by the discoveries of Astronomical Science, and that the fact of such a statement having for so long a period retained its hold over human beliefs, as supernaturally-inspired truth, must now be attributed mainly to its sublime audacity.

Mere observation of the Heavens, or Star-gazing, however long continued, could never have created a Science of Astronomy. The Chinese, the Assyrians, the Babylonians, the Phœnicians, all in ancient times, made and recorded numerous observations of the Heavenly bodies, but they seldom arrived at scientific conceptions. Physical Science indeed is not of Asiatic descent, its parentage is European.

Astronomical Science, that knowledge which enables us to comprehend the past and future state of the system of the World, has resulted from a series of marvellous discoveries made by the intellect of European Man. As Science, Astronomy is even yet the youthful offspring of the unprejudiced reason, being the result of mental calculation, based upon an accurate observation of the Heavenly bodies, by aid of the Telescope, and other modern scientific Instruments.

The discovery of the real motions of the Earth ; and the other Planets revolving round the Sun ; of the laws which regulate these motions ; of the principle of universal gravitation, as the cause of these laws ; of the actual form of the planetary orbits, and the rate of speed at which they are traversed ; so that the future position of the vast celestial orbs, rolling incessantly through space, can be accurately predicted ; has been work accomplished, not so much by the human eye, as by the human brain.

If, when surveying the history of human opinion, we attempt

to range its several schools on one side or the other of a single line of demarcation, we find that the minds of men seem separable into two almost opposite types. The one being that in which the Imagination is found to predominate as the ruling intellectual faculty, the other type being that in which the Reason is regarded as the ultimate arbiter of both what is true and what is right. This remarkable mental distinction appears to have prevailed from very early times. In reference to its organic source, the poet Coleridge has, in one of his writings, remarked, that all men are born to be disciples either of Plato or of Aristotle; these intellectual chiefs of classical antiquity, showing throughout their writings the very marked mental distinction to which I am alluding.

With respect to the bearing of this two-fold intellectual organization upon the times in which we are living, and the subjects that are being so passionately discussed in our day, I will venture to designate the one, which looks to Imagination as its supreme and ruling mental power, *The theological type of mind*: and the other, which relies on Reason as its ultimate appeal and last resort, *The scientific type of mind*. Both types do indeed make use of reason and imagination too, but they are distinguished by this peculiarity, that the theological type reasons from premises which the exalted imagination supplies, under various specious disguises, such as intuitions, facts of consciousness, innate ideas, and the like; whilst the scientific type of mind controls the imagination by the reason, and reasons from premises, directly or indirectly, derived from experience of the facts of Nature.

Of the theological type of mind, Plato is perhaps the most memorable example with which history supplies us. One of the most brilliant thinkers the world has ever produced, he may be said to be the father of that Metaphysical Philosophy which constitutes the body of doctrine that the mind builds up by means of abstract ideas, largely evolved from its inner consciousness, or, at least, based upon its own intuitions and emotions. Hence it is the Philosophy of Plato that has been the great secular authority with Theologians; its abstractedness from the visible or natural world recommending it strongly to their imaginations and feelings.

This theological type of mind not only characterised the culture of antiquity, it coloured deeply the thoughts of men throughout the middle ages, continuing its overshadowing influence, until, as

I am about to show you, it was, to a great extent, displaced by the development of Astronomical Discovery. Meanwhile, however, so paramount was its spirit, that the historian of "Civilization in Europe," Monsieur Guizot, has declared that, previously to the 17th century, all opinions were saturated with it; that questions philosophical, political, historical, were all regarded from a theological point of view; that even the mathematical and physical sciences were subordinated to the dogmas of theology.

We cannot wonder that, in such an intellectual condition of Society, man's conception of the size and nature of the globe he inhabited should be purely imaginary. Passing over the views of heathen antiquity, embodied for the most part in the fascinating fables of the Greeks, and selecting an illustration from times believed to be illuminated on the subject by the teaching of inspired Scriptures, I will cite a work of acknowledged ability, and undeniable authority at the time when it was published, viz., the treatise of Cosmas on the Nature of the World.

In the reign of the Emperor Justinian, about the year 535, there was living at Alexandria a monk named Cosmas, noted for his inquisitive mind, his scientific attainments, and his knowledge of the relation between Science and Scripture. At the request of some learned men he composed and published a considerable work, entitled "Christian Opinion concerning the World." According to this authority the World was a flat parallelogram or plain. In the centre is the Earth we inhabit, surrounded by the Ocean, and encircled by another Earth. To the north is a high conical mountain, around which the Sun and Moon revolve. When the Sun is behind the mountain, it is Night, when the Sun is in front of the mountain, it is Day. The Sky is fixed to the edges of the outer Earth. It consists of four high walls rising to a great height, and then meeting in a vast concave roof. The whole is an immense edifice, of which the World is the floor. The idea that the World could possibly be inhabited on any other side than its flat upper surface was treated generally with incredulous scorn. The great Fathers Augustin and Lactantius especially deriding it, as the preposterous notion that men could exist hanging downwards with their feet higher than their heads!

Such being the generally received opinion, even amongst the learned, of the nature of the Earth and Sky, we must not be surprised to find that their opinions of the destiny of the World,



and man's position in it, were also purely imaginary. In fact their whole system of theological belief rested on the notion that the Universe was ordained for Man!

Of course, if our Earth were the great central object of the Universe, man, being the highest existing object on Earth, would be, apparently, the centre of all things. Accordingly, every startling phenomenon was believed to have some bearing upon his proceedings. The darkness of the Eclipse, the Comet's fiery tail, the dazzling Meteor, were all pointed at as preternatural portents, manifestations of Divine Displeasure, intended to operate on the mind of man, as threatenings, or warnings to him. His whole career is linked with them—

"The warrior's fate is blazon'd in the skies!  
A world is darken'd when a hero dies!"

Turning from the ideal World and its phantoms, which the imaginations of men have created, to the consideration of that real Universe which Astronomical Science has revealed to us, we find that from the earliest ages the scientific type of mind has existed along with the theological type, although, owing to the want of material in the shape of ascertained physical facts and laws of nature (which have been of slow, and comparatively recent, discovery), there were no means for its discipline, or scope for its growth. Still, its nature being to require facts as the basis of reasoning, and to draw its conclusions from real premises, it has ever been the great instrument of scientific discovery. The scientific type of mind was conspicuous in Plato's great disciple, Aristotle, whose method of arriving at real knowledge contrasts very remarkably with that of his illustrious master. Aristotle's method was not to begin with ideas furnished by the mind, but, with the facts of sense derived from observation of Nature. A thing with him was not to be regarded as true, because the Imagination had suggested it, or because it was amenable to dialectical treatment, but, because the Reason could verify it inductively by an appeal to experience.

The Astronomers have been from a very early period the chief exemplars of the scientific type of mind, showing how (in the words of Professor Tyndall) "Imagination, bounded and conditioned by co-operant Reason, becomes the mightiest instrument of the physical discoverer." Observations of the Heavenly bodies,

as accurate as could be made by means of the unassisted senses, or with such rude instruments as at the time could be constructed; carefully, continuously, and systematically recorded, built up by degrees a body of ascertained celestial facts; and, so far back as about 200 years before Christ, we recognise Astronomy (which chiefly then consisted of such observed facts) developing into Science, by virtue of the early Greek geometers applying to it mathematical calculations, whereby they were enabled to detect the principle of uniformity, or law, which regulates the motions of the Heavenly bodies, and so became enabled to predict, to a certain extent, what would be the state of the sky at a future time.

It was during the reign of the Ptolemies (descendants of Philip of Macedon), commenced at Alexandria, some 300 years before the Christian era, that Astronomy, under the munificent patronage of those princes, began to be cultivated as a science of combined observation and theory.

The History, Method, and Instruments of Ancient Astronomy formed the subject of an interesting lecture delivered here in the month of April last by our friend Mr. Seabroke. I can now only refer to a few leading names, but, I may single out Hipparchus, who flourished at Alexandria about 160 years before Christ. It is to him that the origin of Astronomy, as a science of mental calculation, is chiefly to be attributed. He, being a mathematician as well as an observer, well knew that mere observation cannot constitute Science, and the mode in which he applied his reasoning faculty to obtain theoretical results is in the highest degree interesting. One of his many discoveries I will mention, since it is the earliest known example, in the history of Astronomy, of the correction of an apparent fact of sense, by the intellectual comparison of two distant observations. In the days of Hipparchus, the length of the tropical year (an important astronomical datum) was supposed to consist of exactly 365 days and a quarter of a day. Hipparchus approached this problem with doubt and enquiry. He first himself observed a solstice (that is the position of the sun on the longest day), and then proceeded to compare it with a solstice observed by the astronomer Aristarchus 147 years earlier, and thereby he found that the Sun arrived at the same place twelve hours sooner than it should have done if the year were of the length I have mentioned. Hipparchus thereupon worked out mentally the correction, viz., that the true length of the year

was less than 365 days and a quarter by  $\frac{1}{306}$ th part, and that is now known to be almost exactly the true length of the tropical year. But the great importance of this mental calculation of Hipparchus is not so much its result, as its having inaugurated the scientific method of obtaining real astronomical knowledge.

The works of this illustrious man have not come down to us. They perished, along with many other priceless relics of the past, in that great calamity for the human race, the conflagration of the Alexandrian Library. Hence our knowledge of the discoveries of Hipparchus is derived from the work of his celebrated successor, the Astronomer and Geographer, Ptolemæus, or Ptolemy, who flourished about the year 140. He is the author of one of the greatest astronomical books in existence, the *Syntaxis*, as it is called in Greek, more generally known by its Arabian name of the *Almagest*—a most valuable monument of antiquity, since it contains nearly all the knowledge we possess of the Astronomy of the Ancients.

Many of you know that Ptolemy adopted, as the basis of his theory, that system of the world which places the Earth immovable in the centre of the Universe. The Sun, the Moon, and the Planets being supposed to revolve severally in orbits of different magnitudes; the entire Heavens turning round the earth in every twenty-four hours. It had, of course, been matter of very early observation that some few of the more brilliant of the stars move continually about in a very erratic manner. Hence was given to them the name of Planets (from the Greek verb *πλαναω*, to wander). To account for the irregular motions of the Planets, Ptolemy, and his astronomical precursors, had invented an ingenious theory of epicycles and eccentrics, based upon imaginary circular orbits, which was considered sufficient to explain them.

Such in brief was the supposed nature of the Universe that became so well known as the Ptolemaic System, and which, in the long conflict between Science and Theology, maintained its ground for upwards of thirteen centuries!

Now, the Ptolemaic System did sufficiently account for all the appearances that the Heavens presented to the ordinary observer. With reference to the Stars, for instance, it is the same thing to the spectator whether the Heavens, that is all space with its contents, revolve round him in one direction, or the earth on which he stands revolve within them in the opposite direction, that is,

the diurnal phenomena would be in no way different. To believe, however, that the fixed Stars really revolved round the Earth in twenty-four hours required the most enormous stretch of credulity, for, it was generally conceded, what indeed it had become impossible rationally to doubt, that the fixed Stars must be bodies immensely distant from the Earth, as it had been also matter of observation that these Stars, no matter from what point they were viewed, manifested not the slightest variation of position amongst themselves. The nicest measurement of the apparent angular distance of any two Stars from each other, at whatever point of the Earth's surface (I might almost say the Earth's orbit) it is performed, gives results actually identical; that is, the fixed Stars present to the spectator no parallax (the astronomical name for any variation of such angular distance when found to exist). In other words, the dimensions of the Earth, large as it is, are simply imperceptible when compared with the vast distance which separates the Stars from the Earth.

If, then, the Stars were so immensely distant, and of such enormous size, as they were thus shown to be, to suppose that they could nevertheless revolve round the Earth in twenty-four hours is rationally inconceivable. To the theological type of mind this difficulty of conception was of course as nothing, but, to the scientific type of mind, the difficulty is insuperable; for science, being based on the conviction of the uniformity of Nature, views the Heavenly bodies and their movements, not as without, but, as within the pale of analogy and experience, and regards Astronomy, not as a mystery, but as a Science of cause and effect.

When, therefore, about the year 1537, Copernicus (adopting the opinion of Pythagoras) propounded his geometrical conception, based upon the supposition of the Earth's double motion, its rotation on its axis, and its translation through space in an orbit round the Sun, a rationally conceivable account was given of every motion that the Heavens presented to the Astronomer; an account showing that they could all intelligibly cohere without contradicting each other, and without any violation of the nature of things as concluded from human experience. It was, indeed, though not altogether original, a marvellous conception, for Copernicus neither did nor could, in the then state of science, explain the mechanical origin of the movements he supposed, or assign them any dependence on physical causes. That, however,

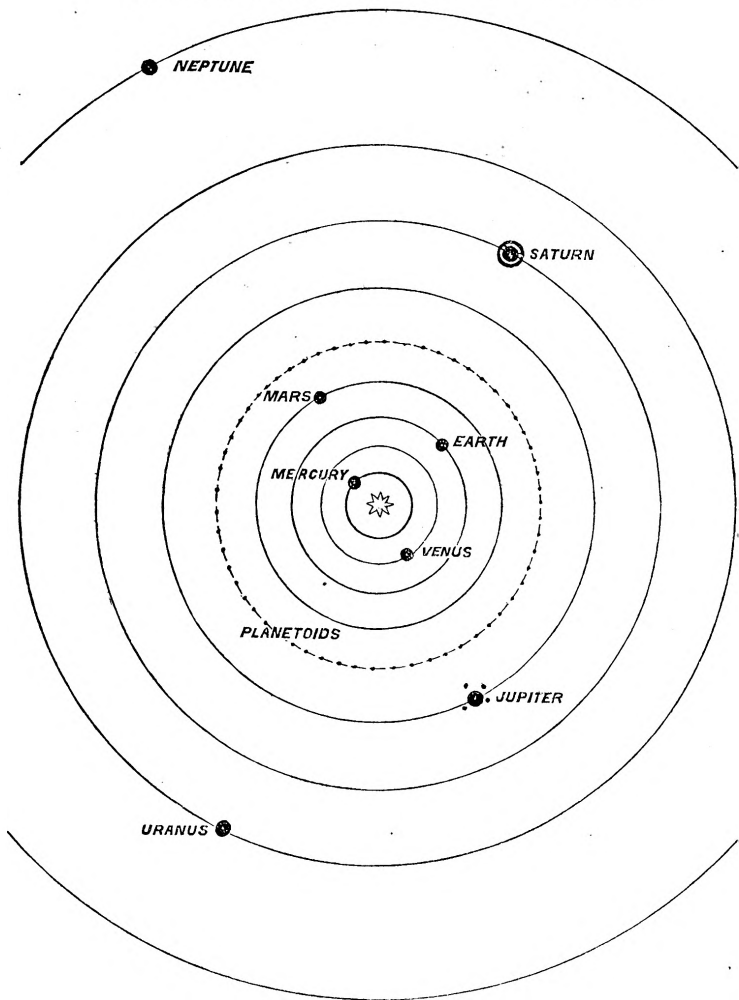
was subsequently done, as we shall presently see when glancing at the discoveries of Kepler, of Galileo, and of Newton.

\*This is an ordinary representation of the chief features of the Copernican or Solar System, showing the Sun in the centre, and the several principal Planets in their respective orbits 'round the Sun. It represents what the eye would see if looking down on the system from a great elevation on the north side. It has, however, one misleading feature, to which I beg your particular attention. It shows the orbits of the several Planets as *Circles*. Such is not the real fact. It was indeed long supposed that the Planets moved in circles round the Sun. It was strenuously argued that they must do so. It was, however, discovered that they don't—that they move not in circles, but in ovals of peculiar mathematical form.

Many were the objections raised against the startling theory of Copernicus. The chief of them was that it contradicted Scripture, which had taught people that it was the Sun, and not the Earth, that moved. Amongst others, it was urged, with regard to the Planets that are nearer to the Sun than the Earth—Venus for example—that if she so revolved round the Sun, she would show, when looked at from the Earth, various phases as our Moon does, that is, she would be seen at times partly in shadow, and so exhibit a broken, or crescent-like shape; whereas, in point of fact, nothing of the kind, as respects the Planet Venus, had ever been observed. Many of you have probably often gazed upon this brilliant and singularly dazzling star without ever having observed any peculiarity of shape about it. In truth, the objection was, at the time, unanswerable, and was by many accepted as fatal to the truth of the theory. But, the year 1609 saw the production of one of the most wonderful instruments ever invented by human ingenuity, which may be said virtually to have connected the eye of the mind with the eye of the body by means of a new sense, enabling the observer to see the Heavens with a precision, and to an extent, hitherto undreamt of, and, when *the Telescope*, in the grasp of Galileo, was turned towards the Planet Venus, the phases attributed to her by the Copernican theory appeared, actually as the testimony of the Heavens themselves, in attestation of its accuracy!

\* See Diagram, page 14.

14 *The Influence of Astronomical Discovery in the*  
**COPERNICAN OR SOLAR SYSTEM.**

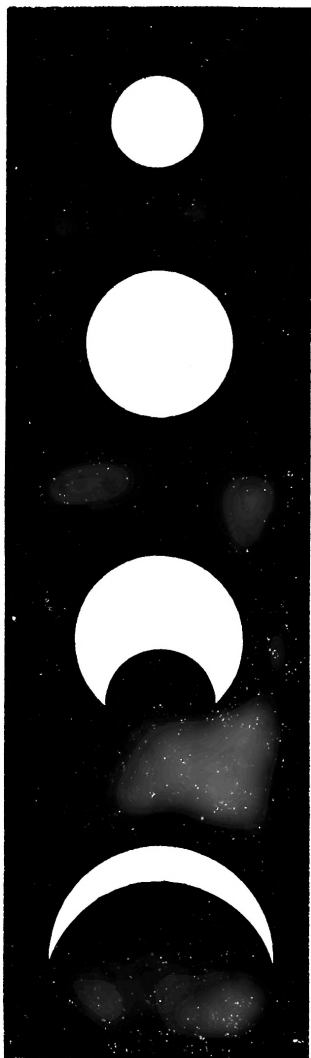




Here you see the phases of the Planet as the Telescope shows them. They are photographic as well as telescopic appearances, but they show clearly the various optical sizes and shapes of the Planet resulting from her moving in an orbit round the Sun interior to that of our Earth.

Still several important details remained unexplained. For instance—the observed motions of the Planets seemed still so erratic, that the complicated scheme of cycles and epicycles had been retained by Copernicus to account for them. At length the actual form of the orbits of the Planets was discovered by the Astronomer Kepler, and subsequently elucidated in a manner that proves a most remarkable coincidence, not to say identity, between the reason of man and the reason that regulates the movements of the Universe!

Now, some 1800 years before the Astronomer Kepler discovered the precise form of the planetary orbits round the Sun, and the beautiful laws which regulate them, the Mathematicians of Ancient Greece had acutely divined, that if a right-angled triangle be made to revolve round one of its sides containing the right angle, there will be described a figure having very remarkable properties, destined (though undesigned by them) to lead eventually to very surprising results.

PHASES OF VENUS AS SHOWN BY THE TELESCOPE.



This is a right-angled triangle  and, if I were to make it revolve round its vertical side as a fixed axis, the figure so described would obviously be this. This figure, in its solid sugar-loaf shape, is termed a Cone, and, if it be intersected or cut by a plane in certain particular directions, there are produced several distinct forms of Curves. 

This is the figure of a *right Cone*.\* If it be intersected in a line parallel to its base, the resulting closed curve is a Circle. If cut through at an angle to its base, the resulting closed curve is an Ellipse. If cut parallel to one of its sloping sides, the resulting curve is a Parabola, and if the plane cut only one side of the cone, and not parallel to the other, the curve produced is the Hyperbola.

Now these Curves, or Conic Sections, are susceptible of mathematical treatment of a singularly interesting and elegant character, and the ancient Greek Geometers, particularly Apollonius and Archimedes, have left us mathematical works showing that they took intense delight in following out such speculations.

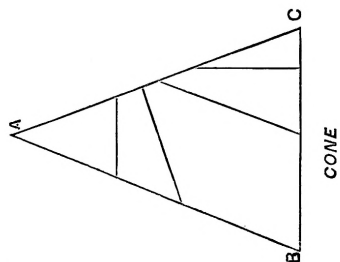
Why they should have been thus fascinated cannot be doubtful to us, for the vast development of physico-mathematical science in our day has shown conclusively that the intellect of man is so constituted as to be ever in affinity with scientific truth, to have a natural relish and love for it; and the Greek Geometers, in their invention of Conic Sections, had lighted upon a truth of Nature of the most expansive and recondite character, although they neither knew nor suspected what they led to, and what the illustrious Kepler, by their assistance, discovered, viz.: That the Planets actually move round the Sun in that one of these Conic Sections termed an Ellipse (the Ellipse and a planet's Orbit are, you observe, in form identical†); and, moreover (as was demonstrated by Sir Isaac Newton), regard being had to the laws of motion (discovered by Galileo), and the principle of universal Gravitation (discovered by Newton himself), it would be physically impossible for the Heavenly bodies to move in any other orbit than one or other of the Conic Sections!

Thus then there became revealed the immense chain of truths that connects geometrical propositions conceived by the reason of man with the most sublime and majestic phenomena of Universal

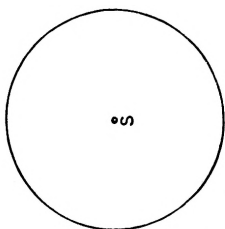
\* See Diagram, page 17. † See Ibid, and Diagram, p. 23.



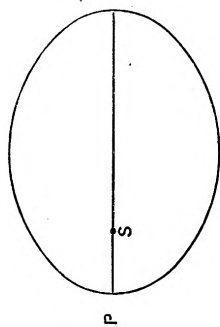
**CONIC SECTIONS.**



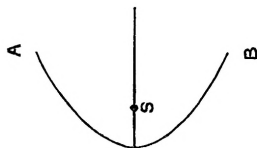
**CONE**



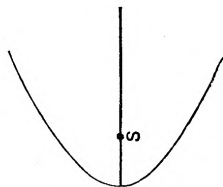
**CIRCLE**



**ELLIPSE**



**PARABOLA**



**HYPERBOLA**

Nature, showing them to be the unerring results of the operation of mathematical, that is, intellectual, Laws!

As our argument particularly regards Astronomical Discovery as resulting chiefly from the exercise of the human reason, I will try to show you somewhat more distinctly some of the great intellectual truths that the genius of Kepler, of Galileo, and of Newton, combined, succeeded in establishing.

Copernicus had not in reality attacked the principle of the Ptolemaic or Epicyclical theory. He had rather sought to render it more simple; and, though he had correctly pointed out that the Sun was the centre of the planetary system, he had not discovered that the Sun had any physical connection with the Planets as the centre of their motions. Now, Kepler, in the course of his consummate researches, demonstrated the important fact, that the planes of the orbits of all the Planets, and the lines of force joining their apsides (the points of their orbital extremities) passed through the Sun; thereby establishing a most important relation between the Sun and the Planets. This family connection (as it has been called) Kepler further demonstrated by discovering the three remarkable laws which regulate all the planetary motions.

The first of these celebrated Laws is: That a Planet moves in the Conic Section termed an Ellipse, having the Sun, not in the centre, but in one of its foci. The second law is: That the Planet's radius vector (an imaginary line joining the Planet to the Sun\*) will, as it moves, describe about its centre equal areas in equal times. A full explanation of these two laws would involve us in mathematics, but presently I will give you an illustration showing the peculiar combination of force by which the elliptic orbit is formed, and equal areas swept out by the Planet's vector in equal times. Kepler's third law applies to all the Planets considered in conjunction with the Sun as their common focus, and may be expressed thus: That the squares of the times of the planetary revolutions are proportional to the cubes of their mean distances from the Sun; which is a result of the Sun and the whole of the Planets reciprocally affecting one another.

It is a necessary inference from this law that it must be one and the same force (subsequently discovered, as we shall see, by Sir Isaac Newton), modified only by distance from the Sun, that retains all the Planets in their respective orbits round about the Sun.

\* See Diagram, p. 23.

Such were the three remarkable Laws whose discovery we owe to the sagacity of Kepler. Their immutable truth may be taken as conclusively proved, inasmuch as, since Kepler's time, the number of discovered bodies in our Solar System has more than trebled, and all have in turn verified these laws.

Upon these propositions of Kepler it was reserved for Sir Isaac Newton to bring to bear those matchless powers of generalization which enabled him to discover the cause of the whole of them, aided, however, by the acute discoveries of the laws of motion by Galileo (Galileo, whose persecution by the infallible Church, on account of his scientific verification of the Earth's motion, is at last becoming a common place of history!).

Galileo then discovered the first great Law of motion or inertia, viz.: That all motion is rectilinear and uniform—that is, a body impelled by a single force will move in a right line, and with an invariable velocity. He also discovered the Law of acceleration, which regulates the motion of a falling body, viz.: That the velocity and the space traversed are proportioned—the one to the time and the other to its square. He also discovered that most important law of the co-existence of force, viz.: That any motion common to all the bodies of any system whatever does not affect the particular motions of such bodies with regard to each other.

At length came the grand discoveries of Sir Isaac Newton, up to which I have desired to lead you through the discoveries of his predecessors, because it is commonly supposed that Newton's discoveries were something immeasurably superior to, and utterly unlike, everything that had gone before—That in short

“Nature and Nature's laws lay hid in night;  
God said—‘Let Newton be!’—and all was Light!”

This, however, is more of a poetic fancy than a scientific truth. The magnificent genius of Newton required no such flattery at the hands of his countryman. In point of fact Newton's illustrious precursors, whose discoveries we have been considering, and other Astronomers, especially Huyghens, Borelli, Halley, and Hooke, whom I can now only name, had approached exceedingly near to what Newton accomplished, so that his grand discoveries, though going further, really supplement and harmonise with their previous labours, illustrating clearly the law of continuity that regulates, by successive steps, the graduated progress of human intelligence.

It should be remarked too, because it has been often thought otherwise, that though Newton, in the propositions of the "Principia," has described his discoveries through the medium of a singularly concise mathematical synthesis, yet (as pointed out by Laplace in his "Système du Monde") Newton actually made those discoveries by following the analytical method of Induction, so luminously expounded by Lord Bacon in the aphorisms of the "Novum Organum."

The great discoveries of Sir Isaac Newton, as mathematically developed in his immortal "Principia" (published in the year 1687), were mainly these. His chief discovery was that of the Law or Principle of Universal Gravitation, viz.: That every particle of matter in existence attracts every other particle with a force, varying inversely as the square of their mutual distances, and directly as the mass of the attracting particle. It is related that Newton was led to arrive at the knowledge of this fundamental law of the Universe by observing an apple fall from a tree before him, and, though the anecdote is not well authenticated, there seems nothing improbable in conceiving that, though a common incident to common minds, it should have roused such a mind as Newton's to reflect upon it. It is certain, however, that he first tested his discovery by applying it to the observed motions of the Moon, and it is an attested fact, that, on finding his calculations were about to show results verifying his hypothesis, he became so agitated as to require the assistance of a friend to complete them. Thus Newton developed his grand thought, that the movements of the Heavenly bodies occur according to the same laws as the movements here on Earth!

Newton's second great discovery consisted in demonstrating as mathematical truths the laws of the planetary motions discovered by Kepler, showing that they are the result of the attraction of gravitation, a centripetal (or centre-seeking) force varying inversely as the square of the distance of the Planets from the Sun as their focus, and proving mathematically that no curve can be the trajectory of a body moving in obedience to such a force other than the curve of one or other of the Conic Sections!

These amazing discoveries enabled Newton to ascertain that the most mysterious Comets are members of our Solar System, moving periodically round the Sun in elongated ellipses.

Now, as soon as it is ascertained that a Comet moves in an ellipse, it is known that the Comet must return to us—the ellipse

being a closed curve.\* Hence Newton was able to calculate and define precisely the elliptic orbit which takes the great Comet, whose reappearance has been recorded but four times within the period of human memory, exactly 575 years to go away and come back to us again!

Thus became established the fundamental truths of the Copernican system; the Ptolemaic theory of eccentrics and epicycles completely overthrown; the elliptical theory established in its stead; and the motions of the Heavenly Bodies, especially the Planets, shown to be the effects of mathematical laws. The elliptic elements of the Planetary Orbits I will now very briefly try to explain.

The orbital motion of a Planet round the Sun is the resultant of two forces. The one is a force, which, by itself, would simply cause the Planet to move in a right line and with constant velocity. How such a force originated, or what the cause of it, is, at present, unknown. It may be, as Mary Somerville defined it, an impulse or momentum imparted to the Planet when it was first projected into space. The other force is one, whose nature as we have seen, was discovered by Sir Isaac Newton, viz.: The attraction of Gravitation. By itself, it would simply cause the Planet to fall or be drawn into the Sun, by reason of the Sun's vastly superior relative size. This latter force, combined with the former, deflects the right line of the Planet's motion into a curve.

I will give you a simple illustration of the combination of these forces:—

Suppose this small ball to represent a Planet, and this large ball the Sun, my hand as imparting to the Planet its momentum, or force of projection, and this string, connecting the two, to represent the force of gravitation attracting the Planet to the Sun. Now, if the force of the Planet's projection were perpendicular to the force of gravitation, and if the two forces acted simply in balanced combination, the velocity of the Planet would be constant, and its Orbit round the Sun would be exactly the Conic Section termed a circle. (*The small ball is whirled round.*)

Now, if the force of gravitation were to cease, that is, if my string were to break, the Planet would not continue a curved motion, but would fly off its orbit at a tangent. (*Marked on the*

\* See Diagram, page 17.

*diagram.\**) If the Planet's momentum were destroyed, the Planet, yielding to the force of gravitation, would fall, or be drawn into the Sun.

The two forces, however, do not affect the Planet equally; the direction of its momentum not being perpendicular but oblique to the force of gravitation, and the force of gravitation varying inversely as the square of the distance of the Planet from the Sun. Hence the Planet moves, not with a constant, but with an ever-varying velocity, and in an Orbit, which is not circular but elliptic, or oval.

A B C D show the elliptic path of P a planet round S the Sun†. The Planet moves from C to D in the same time that it moves from A to B, although the distances differ, by reason of the area C S D being equal to the area A S B.

Now this equal movement is thus effected. Bear in mind that the force of gravitation varies inversely as the square of the distance of the Planet from the Sun; so that when this varying force of gravitation (*represented again by this string*) is increased, which of course it is as the Planet approaches the Sun, there is an increase of its angular and linear velocity, and a rapid quickening of its periodic time, showing the compensation by which its equable description of areas is maintained under a constantly diminishing distance. Thus (*as the small ball is whirled round, the string is wound upon the handle*), you observe that as the distance of the Planet from the Sun *decreases*, its motion becomes more *rapid*. Now, such is the nature of the Planet's motion taking place in one part of its orbit, *viz.*, *from C to D*, where it is being drawn nearer to the Sun.

On the other hand, when the varying force of gravitation is diminished, which of course it is as the Planet passes away from the Sun, then the Planet's time is slower, whilst the velocity is lessened. Thus (*as the small ball is whirled round, the string is unwound from the handle*), you observe, that as the distance of the Planet from the Sun *increases*, its motion becomes *slower*. Now, such is the nature of the Planet's motion taking place in another part of its orbit, *viz.*, *from A to B*, where it is receding further off from the Sun.

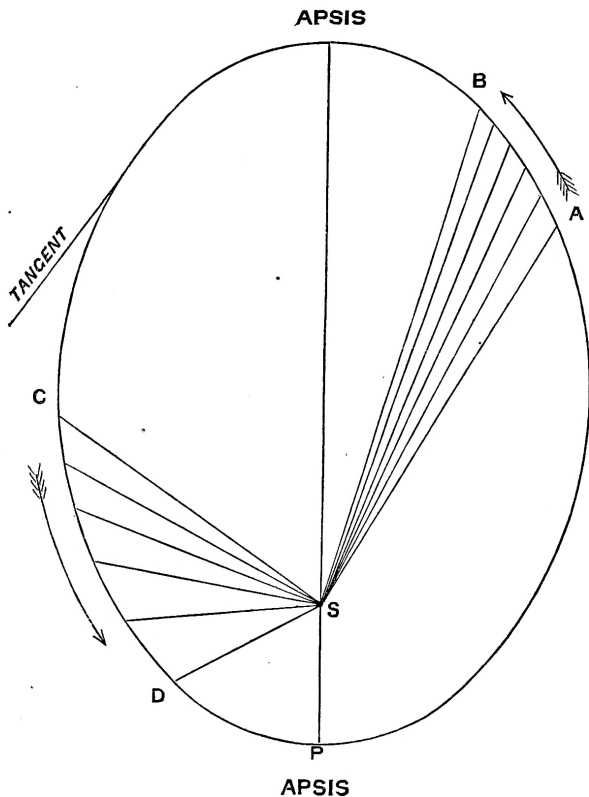
The combination then of the oblique direction of the Planet's

\* See Diagram, page 23.

† Ibid.

ORBIT OF A PLANET ROUND THE SUN.

*Slowest in Aphelion.*



*Fastest in Perihelion.*

momentum, with the ever-varying force of gravitation, compels the Planet to move in the Conic Section, termed an Ellipse, and causes the radius vector of the Planet to sweep out equal areas in equal times.

Such is the rationale of the astonishing phenomena first discovered to be Physical Laws by Kepler, and afterwards demonstrated as mathematical truths by Newton!

Remarkable corollaries have since been deduced from the Copernican System, especially by the Astronomers Clairaut, Lagrange, and Laplace.

We owe to the Astronomer Lagrange the demonstration of the stability of the system. The conclusion he arrived at was indeed most astounding. He discovered that the mean distances of the several planets are really not subject to any variation whatever. They are merely affected by a series of inequalities and inclinations that in successive periods mutually compensate themselves; so that, throughout an indefinite lapse of ages the mean motions of the planets, including our Earth, must have remained, and must still remain, unaltered—a striking proof of the unerring order which reigns among the vast bodies of the Universe, and of the immutable laws by which they are controlled in their courses.

The great geometer Laplace supplemented his abstruse astronomical researches by the composition of a work (*Traité de Mécanique Céleste*), showing that the entire mechanism of the celestial bodies is strictly in accordance with the principles and laws of mathematical science. This profound and luminous treatise of Laplace is the most wonderful performance perhaps (Newton's immortal "Principia" excepted) that has ever proceeded from the human pen. In it, all that had been perceptible to the eye of scientific analogy, or could be theoretically deduced from the great Newtonian principle of Cosmical order, is so fully developed and mathematically demonstrated, that at length this material mechanism of the Heavens comes to strike the astonished student as being, in itself, the very highest exponent of mind!

I cannot conclude this rapid and imperfect sketch without some reference, however slight, to the brilliant discovery of the Planet Neptune by the Astronomers Leverrier and Adams, in the year 1846. The Planet Uranus\* showed such perturbations of its orbit as made it appear a conspicuous exception to the laws of Kepler. The cause of these perturbations was surmised by Adams to be

\* See Diagram, p. 14.



the attraction of some undiscovered body in the Heavens, at such a distance, and of such a mass, as would exhibit an attractive force sufficient to account for them.

On this hypothesis Adams proceeded to calculate from the irregularities in the motions of Uranus, as data, what should be the mass and the elements of the orbit of the disturbing body, and what therefore would be the exact spot in the sky in which it should be found, and he forwarded his calculations to the Astronomer Royal. The disturbing body, thus pointed at, was soon afterwards found (by Dr. Galle) in the place indicated, being the planet to which the name of Neptune\* has been given.

The amazing difficulty of working out such a recondite mathematical problem can be conceived. Indeed, the intellectual grandeur of this discovery surpasses probably everything preceding it, and, by the test of resolving the inverse problem of perturbations—that is, “given the disturbance, to find, as unknown quantities, the orbit of the disturbing body, and its place in that orbit,” corroborates conclusively the truth of the theoretical views of Copernicus, of Kepler, and of Newton.

Thus have I essayed to lead you to the threshold of the Sanctuary of Astronomical Science. Time does not permit, even if I possessed the power, to lift the veil, that we might behold the intellectual treasures of the Shrine within!

Here then we may pause; to contemplate with more intelligence than the Chaldean of old, but, with none the less reverence, the glorious splendours of the starry host! “Heaven’s golden alphabet, emblazed to seize the sight!

“The prospect vast, what is it? viewed aright,  
’Tis Nature’s system of Divinity;

\* \* \* \* \*

’Tis elder Scripture, writ by God’s own hand,  
Scripture authentic, uncorrupt by man.

\* \* \* \* \*

’Tis unconfined

To Christian Land or Jewry; fairly writ,  
In Language universal to Mankind,

A Language worthy the Great Mind that Speaks!”

Though my sketch of so lofty a theme has necessarily been of the slightest character, I hope I have succeeded in showing you that the noble Study of Astronomy, though, by reason of the

\* See Diagram, p. 14.

stupendous phenomena with which it deals, does not, like Chemistry, permit of experiment, yet presents to us the purest type of true scientific method, viz., the free and unbiassed exercise of the highest powers of Reason upon the most carefully observed facts and phenomena of Nature; proving that these are subject to invariable Laws, and imparting to man, whose life, even whose species, occupies a mere point in the duration of the World, knowledge that embraces myriads of ages.

And now let us endeavour to realise the more striking effects of the marvellous Astronomical Discoveries that have revealed to us the true system of our Universe.

The first idea that must occur to us is, that our point of outward view should be the surface of the Sun. Taking our intellectual stand at the Sun,\* the Heavenly bodies of our system appear before us in all the Majesty of the Divine Order of their due proportions. Our Earth is seen, as it really is, not the world, but comparatively a very small globular star, not the centre of anything, but, circulating in its place and season, among the other planets, round the Sun.† The petty theological schemes, that were composed by men when they believed the earth to be a flat plain, the centre of the Universe, disappear altogether, like ghosts before the rising light of dawn!

Our views then, whether religious or otherwise, are at once corrected, expanded, and elevated, to a degree that must convince us that not only are isolated statements in the Hebrew Scriptures discredited, but that the whole Theology of the Christian Fathers is deprived of its fundamental basis.

Our knowledge, derived from Astronomy, of the small size, and double motion, of the Planet we inhabit, has, in truth, destroyed intellectually every system of theological belief that has been based on the notion that the entire Universe was ordained for man.

But, more than this, Astronomical discovery has proved to us that the order maintained on Earth, and throughout our System, is not dependent upon theological dogma, however much belief in it be backed up by authority and tradition, but, results from the universal simple gravitation of its parts. For gravitation not only regulates every physical effect; there can be no mental calculation, no moral feeling, no social custom into which the law of gravitation has not, in some shape, at some time, entered as a factor.

\* See Diagram, p. 14. † Ibid.

Another most important consequence has been this. Previously to the proof obtained through Astronomical discovery of the permanence of the surrounding physical conditions of life (so conclusively demonstrated by Lagrange), the very conception of stability in human association was inadmissible. Anything like a social science was impossible. Even attempts at social improvement seemed waste of energy, for, in the ignorance of its astronomical conditions, it was believed that the World was shortly coming to an end! and, indeed, as a device designed by Priestcraft for exciting terror, the notion that the World was shortly coming to an end was assiduously asserted, and as credulously accepted. In the early ages of Christianity this terrorising conception was thoroughly believed in. The Christian Gospels were interpreted as being saturated with its spirit. John the Baptist and Christ himself were understood to be clear and emphatic that the end of all earthly things was at hand! Of course such a prospect completely paralysed all attempts to improve the conditions of social life. To retreat from the World to a monastery or a nunnery, there to await the awful event, seemed the only wise and holy course.

In the 10th century the minds of men were so impregnated with this appalling opinion that people of wealth and intelligence actually commenced their last Wills and solemn documents with language such as this: "In the expectation of the approaching end of the World I devise and bequeath," so and so.

In the 16th century the inhabitants of Europe were nearly driven mad with fright by a theological prediction of a second Deluge being about to happen. The people of Toulouse in France building themselves a huge vessel, after the pattern of Noah's Ark, to save themselves from the expected impending destruction! But the predicted day came and passed, and still the Seasons run their appointed courses.

The disastrous influence of this demoralising dogma can of course be imagined. Astronomical discovery, in showing the permanent stability of our Solar System, has at length, in the minds of nearly all rational persons, utterly exploded it.

Another scarcely less important deduction from Astronomical Science is this: it exhibits the Universe as a region of uniformity or realm of Law, and the Laws of Nature as Laws of Reason. For, it is obvious, from the regularity of its grand disclosures, that our World is ruled by Natural Law, and not by Supernatural

Will. That one reason pervades and governs all Nature, and that, unless the laws of our Reason and the laws of Nature were identical, it would be impossible to comprehend the latter to the extent Astronomers have done. It has proved to us also that the reign of Reason dominates the dominion of the Imagination; for Astronomical Science, fathoming the abysses of space, has measured magnitudes, computed distances, and calculated results (proved in verified predictions) that are utterly beyond the realisation of the human Imagination.

Astronomical discovery also shows (I know not why we should shrink from its avowal) that the Reason pervading the Universe, and the Reason of man flow from, or are correlated with, a material source.

The Astronomer, who has weighed the worlds, penetrated space to the depths of infinity, and learnt the laws that rule every motion of the heavenly bodies, still finds himself in presence of a mystery, and, reflecting upon the material brain that produces thought, the material cone that yields its curve, the material globes of heaven winging their measured flight in orbits, whose curvature thought has formulated, the material principle of universal gravitation, that human thought has unveiled, the material energy that brings us light from the remotest stars, feels impelled to ask (and, like the physicist, he asks in vain)—divorced from Matter, where is Mind to be found?

Astronomical discovery has also revealed to us an Order of Nature, as the Criterion of objective Truth, and the Area of real Knowledge. It has also supplied us with a just Standard of Proportion—as regards external Nature, in proving to us that our Earth is not the World, but only a very small proportionate part of it—as respects the Human Mind, in proving to us, that the Imagination cannot rightfully be the dominating intellectual faculty, since the Reason is shown to excel it.

Astronomical discovery has also armed man with a real power of Prediction, that is, a power enabling him to foretell beforehand events that will happen, and to indicate clearly the precise time and place at which they will appear. All of you know that, either in the Nautical Almanac, or the periodical press, it is pointed out long previously when there will occur an eclipse of the Sun or Moon, or an occultation or transit of a Planet, or an extraordinary high Tide, even the return of a Comet, and you know, by your own

experience more or less, that such prediction is exactly fulfilled to the day and hour. In this precise power of prediction, Science, whose great object is prevision, *savoir pour prévoir*—to see in order to foresee—has effectually rescued herself from all Theology and Metaphysics, whose mystifying and interminable controversies, now continued through more than 2,000 years, have never been able to prophecy accurately anything. The whole compass of sacred literature does not contain a single undisputed instance of a theological prophecy being even so much as intelligible until *after* the happening of the event, which then indeed, but not until then, is alleged to have been predicted.

Another most ennobling influence on the human mind of Astronomical Science has been its extirpation of Superstitions, or Beliefs inconsistent with the unbiassed dictates of Reason, and the experienced course of Nature. This it has accomplished in showing that the basis of all our real knowledge may be traced by our Reason to the laws of Astronomical phenomena, and so accounted for, without any necessity of resorting to the supposition of supernatural interference, or the intrusion into the course of life of any providential power contrary to the order of Reason.

Again, Astronomical discovery, in encouraging a love of enquiry in the spirit of Truth, has both invigorated Culture and reformed Education. Previously to the growth of Astronomical Science and the subsidiary sciences to which it led, especially biological science, with which Astronomy is closely connected (it being impossible to form a scientific conception of the conditions of vital existence without taking into account the Astronomical elements that characterise the planet which is the home of that existence), the principle branches of the higher Academical Culture consisted in the study of the Mythology, the History, and the Literature of Classical Antiquity, the verbal Logic of Aristotle, and the Theology and Metaphysics of the early Christian and Middle Ages, usually accompanied by a course of Mathematics, though, respecting the utility of mathematics, a difference of opinion actually prevailed. That intellectual refinement and fastidious taste were produced by the discipline of these studies is undoubted. They were, however, not rarely accompanied by a want of appreciation of the Truths of Nature, by a tendency to believe whatever was inculcated by authority, and by an inordinate reverence for whatever was old: and the result was sometimes seen in an emasculation of mind, or

atrophy of the investigating and sceptical faculties. The essence of such a curriculum might almost be distilled into a single phrase—The Cultivation of Credulity!

Science has very considerably improved all this, and if we look at the course of studies now pursued at our academies, even at the old conservative Universities of Oxford and Cambridge, we perceive that an attempt is honestly being made to impart to Youth some portion of that positive or scientific knowledge which forms the backbone of our European Civilization; and that the object in view, in the training of the mind, is no longer to impress upon the scholar—"To acquiesce, to remember, and to believe"—but, "To doubt, to enquire, and to compare." In one important study, that of Mathematics, their transition, through the advance of physical science, from pure to applied—that is, their alliance with, or application to, the facts and processes of Nature, has converted mathematics, from being used as a basis of mere dialectics, into the most powerful deductive instrument for the discovery of the Laws of Natural Phenomena, and for the verification of scientific knowledge.

Lastly, I will add, that, when we call to mind the false theological views of the nature of the World we inhabit, the spurious theological beliefs respecting its method of government, which Astronomical discovery has exorcised, setting free the mind from the fear which they inspired, we cannot doubt how greatly it has aided in the purifying of Moral Principles, and in the increasing of Human Happiness.

Human happiness, the greatest good of social man. Virtuous happiness was the goal which the speculations of Plato were intended to reach, and it was the ethical standard at which were aimed the lifelong studies of one whom I am now going to name in contrast with Plato,—John Stuart Mill.

If the occasion permitted, willingly would I dwell on the many points in common that characterised and adorned the genius of these greatly-gifted men; each of whom was endowed with an order of mind the loftiest which our species has ever exhibited. But the one, Plato, as we have seen, lived before the rise of Astronomical Science, and those subsidiary sciences that have followed its lead; whilst the other, Mill, presents to us the ripest results of scientific culture. Both were enthusiasts in their love of right and hatred of wrong; but Plato was a visionary, Mill an utilitarian. To summarise the Philosophy of Plato has ever been

a logical impossibility, for he never seems to have had any steady convictions to guide him. Though the most influential thinker of antiquity, it is difficult to point out any real important truths that he can be said to have established. His subjective method of enquiry accounts for this. He thought that the source of knowledge was Reflection, which gives us ideas—and not Experience, which gives us facts. Hence there is a shadowy unsubstantial vein pervading his writings, which, when deprived of the halo of their exquisite style and language, so charming to the lover of literature, leave a void in the mind of the student seeking to attain some solid foothold for support and counsel in the battle of actual life. How different is this from Mill, who has taught us that all real knowledge is derived from Experience, and that the grand sources of human suffering are conquerable by human energy and scientific effort.

I will mention, by way of further contrast, but a single work of each—Plato's "*Republic*"—Mill's "*Political Economy*." The college recluse may indeed continue to prefer the former, and scornfully smile at the simplicity of our juxtaposition of these celebrated Treatises ; but, to the man of common sense and common humanity, whose pulse beats strongly with the desire of doing something practical towards elevating the moral and material condition of the humblest of his fellow creatures, and who fain would leave his little corner of the world better and happier than he found it—the superiority, in solid truth, in moral worth, in social utility, of the great work of Mill, does not admit of the shadow of a doubt.



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