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ASTRONOMY'S CONTRIBUTION TO THE STREAM OF HUMAN THOUGHT[1]

By President D. W. MOREHOUSE

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Contemplated as one grand whole, Astronomy is the most beautiful monument of the human mind, the noblest record of its intelligence.—*Laplace.*

THE development of human thought frequently has been compared with the formation of a great river. No single source can be named as the origin. Numerous streams from wholly different sources flowing in diametrically opposite directions converge to give it being. Not infrequently it is difficult to determine which is the main stream and which is the tributary.

The changes in its course can not be detected from up-stream. It turns back upon itself at the most unexpected moment and winds in and out among barriers which for the moment seem absolutely insurmountable. As it widens, it becomes shallow and its banks less distinct until new accretions cut deep gorges in the rocks of ignorance. Spring floods, too, have their analogy in the stream of thought. Samuel Butler's warning in Erewhon, "Woe to him who tampers with the banks while the flood is flowing," has been exemplified too frequently in astronomy.

COSMOLOGY

As the various races emerge from their primitive concepts of cosmology, we find some far in advance of others. For example, the Hebrews and the Greeks have been held up to us from time immemorial as the greatest peoples of their time. The Hebrews excelled in their conception of the things of the spirit, and the Greeks in art, science and philosophy. The Hebrews, having little interest in science, disentangled religion from pseudo-science and crude materialism. The Greeks, with their transcendent genius, founded

[1] Address of the retiring vice-president and chairman of Section D—Astronomy, American Association for the Advancement of Science, New Orleans, December, 1931.

science on actual observations and based their theories on facts.

Among the names of antiquity, Thales, Pythagoras, Menton, Aristotle and Plato, one Eudoxus stands out above all others. In point of time, Eudoxus lived 409–356 B. C. He, therefore, touched the life of Plato in his later years and that of Aristotle in his early days. Eudoxus is considered the first inductive thinker of his time. Berry says, "He may be regarded as representative of the transition from speculative to scientific astronomy, and much of his work was taken bodily by Aristotle, who, in common with other philosophers of his time, understood the influence of the concept of the physical world upon the thinking of the times.

Claudius Ptolemaeus
(100–170 A. D.)

The next important addition to the development of thought, after the coming of Christ, was started by Claudius Ptolemaeus, commonly known as Ptolemy. He was the propagator, if not the author, of the first cosmic theory of the universe, popularly known as the geocentric theory. The influence of this man is shown in the greatest work of antiquity, "The Almagest." If any one will wade through its thirteen books, he will find in them the cosmology and the cosmogony of his age. He will not only find the concepts of life, but also the ideas of eternity. There is an air of finality to this book which is not found in any other work of this time. It seemed to predict that the days of science had come to an end. As MacPherson points out:

> The Hellenic culture had largely exhausted itself and an air of hopelessness and futility had settled over the world. The Stoics rather concerned themselves with problems of conduct than with questions concerning the natural world, while the early Christians, expecting the early return of Christ, did not busy themselves with the affairs of this world. Accordingly, slowly but surely, science and philosophy alike seemed to die out.

During the next fourteen centuries, the Arabs, who were largely imitators and commenters rather than investigators, carried on the slender stream of scientific thought.

Nicolaus Copernicus
(1473–1543)

> Every stimulus to the intelligence naturally brings with it a tendency toward inquiry into opinions received through tradition and based on some great authority.

Toward the end of the fifteenth century, astronomy again added a new stream to human thought through the labors of the celebrated Polish astronomer, Copernicus, of whom Thomas Digges wrote:

> But in this our age, one rare witte (seeing the continuall errors that from time to time more and more continually have been discovered, besides the infinite absurdities in their Theoricks, which they have been forced to admit that would not confesse any Mobilitie in the ball of the Earth) hath by long studye, paynfull practise, and rare invention delivered a new Theorick or Model of the world, shewing that the Earth resteth not in the Center of the whole world or globe of elements, which encircled and enclosed in the Moone's orbit, and together with the whole globe of mortality is carried yearly round about the Sunne, which like a king in the middest of all, rayneth and giveth laws of motion to all the rest, spaerically dispersing his glorious beames of light through all this sacred coelestiall Temple.

The life of Copernicus was quite uneventful. He has been dubbed by nearly every writer as a plodder, and yet, no other one thing has so completely changed the trend of human thought as his bold statement that the earth is not the center of the solar system. From the earliest time, the geocentric idea of the universe had held sway. It is quite true that here and there a few lone figures suggested the possibility of another concept, but they were quickly stifled, and the earth and man restored to their position—the end and aim of creation.

One can hardly imagine the profound influence on the thought of the time of Copernicus' great book "The Revolution of the Celestial Bodies," setting forth the new order of things. To some it may seem a pity, to others, a blessing that he did not survive the publication of his book in 1543. At first, it was treated with the utmost contempt by authorities and with furious vindictiveness by theologians. We must remember that at this time the Reformation was at its height; Protestantism and Catholicism were in a titanic struggle with each other; Luther had pinned his theses to the church door, and yet that great Protestant was among the first and most vehement to denounce the Copernican system. He referred to Copernicus as "an upstart astrologer who strove to show that the earth revolved." "This fool," said Luther, "wishes to reverse the entire science of astronomy, but sacred scripture tells us that 'Joshua commanded the sun to stand still' and not the earth." Says Andrew D. White in "A History of the Warfare of Science with Theology in Christendom":

> While Lutheranism was thus condemning the theory of the earth's movement, Calvin in his ''Commentary on Genesis'' was condemning all who asserted that the earth is not at the center of the universe. He clinched the matter by the usual reference to the first verse of the ninety-third Psalm, and asked, ''Who will venture to place the authority of Copernicus above that of the Holy Scripture?''

Suggestions were heard on every side that such views should be forcibly repressed, and some of its advocates, for example, Bruno, were condemned to death and burned at the stake in 1600. As history records, the second martyr of the Jesuits was harassed and persecuted solely for his adherence to the Copernican system.

> The greatness of Copernicus, [quoting from MacPherson] is not to be measured by what he did, but by what he made possible. A vast extent of the universe was revealed, and so the philosophic and theological outlook was vitally affected by the new system. While the scholastics were vainly trying to refute Copernicanism and the theologians were engaged in hurling anathemas at the heads of its supporters, the new system of the world was being established upon a firm scientific basis.

THE CONCEPT OF DYNAMICS

> Bacon pointed out at a distance the road to true philosophy: Galileo both pointed it out to others and made himself considerable advances in it.—*David Hume.*

The century following the death of Copernicus produced three great men of remarkable genius, Tycho Brahe (1546–1601), Kepler (1571–1630) and Galileo (1564–1642), an observer, a mathematician and a physicist. Kepler, who devoted a lifetime to the discovery of the three laws of planetary motion, which bear his name, did not conceive of their dynamical explanation. MacMillan says:

> He was content to ascribe them to the intelligence of an angel who guided the planets in their courses. His was the age of spirits and Kepler's interpretation of uniformities was Animistic. The foundations of dynamics came only with the genius of Galileo, who had little liking for the conceptions of Animism. His *induction* that the natural state of a body was uniform motion in a straight line, and that a departure from that state was due only to force was one of those great breaks with the Past which occur at rare intervals in human history and which have raised the race of men to its present intellectual level. Galileo initiated a new age, the one in which we live, the age of dynamics.

It was the work of Galileo, in his discovery of the revolution and phases of planets, that completely confirmed the Copernican doctrine. Father Inchofer of the Jesuits in denouncing him declared:

> The opinion of the earth's motion is of all heresy the most abominable, the most pernicious, the most scandalous. The immovability of the earth is thrice sacred. Argument against the immortality of the soul, the existence of God, and the incarnation should be tolerated sooner than the argument to prove that the earth moves.

Thus the controversy went on. The very thought of the earth as no longer the center of the universe was the real crux in the situation. If the Copernican system was true, then the entire outlook of human thought was changed, and the old, time-honored cosmology must be discarded. As the earth had lost its position among the heavenly bodies, so man would necessarily lose his supremacy in creation, and endless problems presented themselves.

CONCEPTS OF MECHANICS

Sir Isaac Newton—The Great Mechanist (1642–1727)

> Nature and Nature's laws lay hid in night
> God said, "Let Newton be" and all was light.

Newton completed the work of these men and established the fundamental principles of Mechanics in the "Principia" which, as Laplace has declared, "has a preeminence over all productions of the human intellect." Says Andrew D. White:

> There came, one after another, five of the greatest men our race has produced—Copernicus, Kepler, Galileo, Descartes and Newton—and when their work was done, the old theological concept of the universe was gone. "The spacious firmament on high"—"The crystalline spheres"—"The Almighty enthroned upon the circle of the heavens" and with His own hands or with angels as his agents keeping the sun, moon and planets in motion for the benefit of the earth, opening and closing "the windows of heaven," letting down upon the earth "the waters above the firmament," "setting His bow in the cloud," "handing out signs and wonders," hurling comets, casting forth lightning to scare the wicked, and shaking the earth in His wrath: all this had disappeared.

The Newtonian theory was the natural outgrowth of the Copernican theory and had no less influence upon human thought. The old idea of celestial and terrestrial differences had been positively refuted. The solar system had been discovered. It was now clear that the fixed and law-abiding order of nature prevails not only upon this earth but also throughout the universe. Thus we have the beginning of mechanism—the whole universe reduced to a machine.

Quite contrary to the reception of the Copernican system, this thought was quickly grasped by the theologians. They had here from a profound scientist just what they had been looking for—a perfect system ruled over by a carpenter God. For Newton, in his perfect order of things, proves the existence of a God; an idea which drew from Leibnitz the criticism that "Newton had compared the universe to a clock which required the constant interference of the clockmaker."

Here we find a splendid basis for Deism. Many of the great men of England seized upon this idea and appropriated it to their uses. Through the writings of Ferguson, Paley and Thomas Dick, the mechanistic conception of the universe had a profound influence on human thought and prepared the way for Deism by commending it to the rational faculties. It was Laplace who cried out in protest to this great wave, "I have no need of the hypothesis of a God."

Sir William Herschel, The Artist (1738–1822)

Coelorum perrupit claustra—*Herschel's Epitaph.*

Was it a dream?—that crowded concert-room
In Bath; that sea of ruffles and laced coats;
And William Herschel, in his powdered wig,
Waiting upon the platform, to conduct
His choir and Linley's orchestra?
He stood
Tapping his music-rest; lost in his own thoughts.
—*Alfred Noyes.*

The century that intervened between Newton and Herschel was probably more productive from the standpoint of human knowledge than any other like period. More great scientists and mathematicians arose during this interval than in any other corresponding time in human history. Time will not permit me to speak of the work of such men as Halley, Clairaut, Bradley, Euler, Lagrange, Laplace and Gauss.

They developed the greatest science ever conceived by the human mind, celestial mechanics. In the words of MacMillan, "They erected a monument to the human intellect that can never be forgotten as long as the mathematical faculties of men are active."

Undoubtedly these men lost much of their luster by suffering comparison with Newton. Stars, they were, of the first magnitude, but you can not see a star when the sun is shining.

Such was the condition of the astronomical world when the itinerant musician, Frederick William Herschel, made his way to Britannia: The sole aim of astronomers was the verification of the Newtonian theory, and human thought was completely centered on the solar system. The stars were merely guide-posts from which to take measurements and with which to compare results. What a discouraging situation for an artist! But Herschel was equal to the task which confronted him. By his artistry he transformed the humble guide-posts into monuments of surpassing splendor, by demonstrating what other observers had suggested as probable, "The essential kinship of the sun with the stars." By his observation of double stars, he extended the law of gravitation to the sidereal universe. As MacPherson points out:

> Copernicus had shown that the earth, so far from being the center of the universe, was but one planet among others in ceaseless revolution around the sun. Herschel now proved that the sun itself was not the central body, but was merely one star among others in ceaseless motion through the depths of space.

Newton had shown that the solar system was subject to one law, and Herschel demonstrated that this same law was applicable to the stellar system.

Thus we have the beginning of a new concept, cosmology, or the extension of the universe to a sidereal system. This required new postulates which had never been conceived, let alone proved, and endless observations which had not been made. As before pointed out, everything had been confined to the solar system. Now we must have a new type of observations and an expansion of thought.

The sky was vast and the equipment at hand was meager, but Herschel met both challenges, constructed his own instruments and made a careful survey of the entire sky in duplicate. As a result of his observations, he first formulated the disc or grindstone theory of the stellar system, which he later abandoned, but left his vast store of data to his successors. He was convinced, however, that the Galaxy or Milky Way is a greater system of which the solar system is a mere atom. His theory "that star clusters and nebulae formed universes external to our galaxy" implied an immense extension of the universe not only in space, but in time. As he said, "I have looked farther into space than ever human being did before me," adding more hypothetically, "I have observed stars of which the light, it can be proved, must take two millions of years to reach the earth." What an influence such ideas must have had on contemporary thought is suggested by Horace Walpole in his well-known expression, "One's imagination cracks."

COSMOGONY

The greater the sphere of our knowledge, the larger is the surface of its contact with the infinity of our ignorance.—*Anonymous.*

The ancients generally did not clearly distinguish between cosmology and cosmogony. "There had been implanted," says Andrew D. White, "along through the ages, germs of another growth in human thinking; some of them even as early as the Babylonian period. In the Assyrian inscriptions we find recorded the Chaldeo-Babylonian idea of an evolution of the universe out of the primeval flood or great deep." This thought was adopted by their neighbors, the Hebrews, but was soon stifled by the more powerful influence of their inherited doctrine. The Ionian school developed the idea more clearly. Anaximander, for instance, conceived of the visible universe as the result of evolution, and Aristotle carried it to a point which approached modern views. Notwithstanding the work of these men, the idea of creation in six literal days predominated in the minds of the masses for hundreds of years.

Probably the first great factor that influenced the church to accept these new doctrines was the work of Ralph Cudworth in his "Intellectual System of the Universe," published in 1698. He argued most effectively against the prevailing mechanical theory and set forth the idea of a divine imminence in both theology and science. He says:

> Nevertheless, the substance or matter out of which the world was made was not itself made but always ready at hand, and subject to the artificer, to be ordered and disposed by him. For the making of the world was not the production of it out of nothing, but out of an antecedent, bad and disorderly state, like the making of a house, garment or statue.

It seems extremely difficult to locate the first idea of a nebular hypothesis. The Scottish astronomer, James Ferguson, strongly suggested the idea in the following sentence:

> In the beginning God brought all the particles of matter into being in those parts of open space where the sun and planets were to be found, and endowed each particle with an active power by which these neighboring and at first detached particles would in time come together in their respective parts of space and would form the different parts of the solar system.

History gives the credit of the nebular hypothesis to Wright, Kant, Laplace and Herschel. The first two developed it theoretically and from a deductive point of view. They postulated nebulae out of which solar systems evolved. Their ideas were wholly speculative. Herschel showed by direct observation that there are nebulae and was the first to develop the hypothesis by inductive methods. We know that the nebular hypothesis was received very calmly at first. There were a few outcries against it, but Laplace published it only as a speculative theory; an appendix to his "Celestial Mechanics," and Herschel did not publish his ideas except in scientific papers of the Royal Society, which were not read by the masses. The opposition from the theologians was not more vigorous than from most scientists. The exact nature of a nebula was not known. The question arose as to the difference between nebulae and star clusters. Was it simply a case of optical power of resolution? And again science halted for a time.

From an unexpected source came a new factor, the spectroscope which had no less an influence upon the time than had the telescope of Galileo. Fraunhofer, about the beginning of the nineteenth century, showed that there is an intrinsic difference between a gas and a solid. Immediately his principles were applied to the nebulae and they were found to be gaseous. "As a result," says MacPherson, "The chemical unity of the universe was found to be a truth of nature. The cosmos was seen to be in very truth a cosmos connected and interrelated in all its parts." Quoting further, he says:

> Slowly but surely the mechanical theory was passing away. Even in theology, Deism was giving place to the new sense. In philosophy, the empiricism of the French school was giving way before the idealism of Fichte, Schelling, Hegel and Goethe. And in physics, the whole mechanical concept of empty space and isolated bodies was disappearing.

As expressed by Charles N. Holmes, the universe began to expand before man:

> Above him yawn (ed) abysmal gulfs of space!
> Mysterious, majestic, silent, cold
> Ablaze with stars that shone upon our race
> When Joseph by his relatives was sold,
> Before him loom (ed) the sky like scroll unroll'd,
> Inscribed with symbols gleaming brilliantly,
> Far, far remote, yet those that furthest be
> Reveal no limits save Infinity.

A new problem now arose: What is the form and extent of our universe? If we accept the Copernican or heliocentric theory of our solar system, then what is our concept of the stellar system? The great galaxy or "Milky Way" suggests the existence of two streams of stars, or a spiral nebula, and the work of Kapteyn, Campbell, Shapley, Russell and Hubble, not to mention others, has gone far to establish it as a truth. The idea of "island galaxies" is again coming into favor. "This theory," says Eddington, "is much to be preferred as a working hypothesis, and its consequences are so helpful as to suggest a distinct probability of its truth." In the chemical and physical world we start with the electron as a unit from which we build the atom, then the molecule and finally the ordinary mass. In the cosmic universe the solar systems are the atoms with their planetary electrons. The star clouds and clusters are cosmic materials composed of solar systems, and the galaxies are aggregations of stellar and nebular masses. Says MacMillan:

> It will be observed that ordinary masses are just in the center of our list of physical units. Shall we go back to the old notion that we are the natural center of the universe, or shall we regard this as a mere appearance, due to the fact that it is more and more difficult for us to have experience with those units which are more and more remote from us in the physical scale? We are at the center, because the center is everywhere. Two atoms of gold seem just alike because we are not very familiar with atoms of gold, and two electrons seem to be identical merely because of our profound ignorance. Supergalaxies exist though we have had no experience with them at all; likewise, hypersupergalaxies, and so on indefinitely. Things do not cease to exist merely because we are ignorant. We should beware of the tacit postulate, which often crops out, "Only those things exist with which we have had experience." Nature is much broader than experience, and we must have plenty of room for expansion.

During the nineteenth century cosmogony has been in the hands of an able group of mathematicians, physicists, geologists and astronomers, among whom should be mentioned Moulton, MacMillan, Chamberlin, Kapteyn, Sears, Russell, Shapley, Jeans, Eddington, deSitter and Einstein. The old ring theory of Laplace has been rigorously attacked and found wanting in many of its details. We now have a new idea under the caption of the planetesimal hypothesis in which the modern concepts of dynamics and the structure of matter play an equally important rôle with mathematics. Geology is no longer ignored. The invention and application of the interferometer has verified and greatly extended the postulated sizes and distances of the stars. The new one hundred inch Hooker telescope is resolving and analyzing the star clusters and nebulae in a manner wholly undreamed of a half century ago.

The two solutions of Einstein's fundamental equations, resulting in a finite, static universe as one extreme and an infinite, expanding universe as the other, give promise of a more general solution approaching objective reality. We must not be misled by the first solutions of so difficult a problem. As often happens in pure mathematics, the special cases are the first to appear, then the more generic gradually evolve.

The size and shape of the universe is probably no more impossible of solution to-day than the size and shape of the solar system was in Ptolemy's day. To our finite minds a universe that requires a beam of light five hundred thousand million light years to circumnavigate it is infinite, but as Sir James Jeans says, "We are not terrified by the sizes of the structures which our own thoughts create, nor by those that others imagine and describe to us. The immensity of the universe becomes a matter of satisfaction rather than awe; we are citizens of no mean city. Again, we need not puzzle over the finiteness of space; we feel no curiosity as to what lies beyond the four walls which bound our vision in a dream."

Schiaparelli once called astronomy the science of infinity and eternity and the description is just. "These words," says MacPherson, "are often used by philosophers and theologians. Astronomy gives some definite sense of what they mean. The concepts of infinity and eternity are soul-staggering, but they are less difficult than those of limitation of space and time. To the higher thought, the chief contribution of modern astronomy is doubtless this sense of the infinity of space and the eternity of time."

THE PHYSIOLOGY OF CONSCIOUSNESS[1]

By Professor EDWIN G. BORING

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MY thesis this evening is that scientific psychology needs more than to become the physiological psychology that Wundt originally called it, and that we are not entirely without the means of proceeding in this direction. Psychology, it seems to me, needs to save for its own uses both consciousness and the nervous system, and it must have both if it is to survive.

Once upon a time psychology had some hope of getting along without a nervous system. There was a time when introspectionists, like Külpe and Titchener, would have hailed with avidity any step that brought psychology nearer to being a descriptive science of the facts of experience, a science that could get along with introspection as its only method and could leave the nervous system and the stimulus ruthlessly in the outer darkness of physiology. There is no need to explain to this audience that the introspective method unsupported failed to yield a psychology, or perhaps even a single factual generalization.[2] The most satisfactory introspective experiments were those that resulted in the correlation of sensory or perceptual data with stimulus. The best theories were formulated in terms of the nervous system or the sense-organs. Unaided introspection proved inadequate in crucial cases, as in the problem of thought where we were left with only a "physiological" determining tendency as a principle of explanation.

The reaction of behaviorism against this state of affairs by the complete rejection of the introspective method was very natural, even though it represented a throwing out of the baby with the bath. Theoretically you can answer for animals, by tests of discrimination or by observation of conditioned reflexes, any of the questions about sensory or perceptual

[1] Address of the retiring vice-president and chairman of Section I—Psychology, American Association for the Advancement of Science, New Orleans, December 29, 1931.

[2] There never were any laws of introspective psychology other than those that state the correlation of conscious processes with the stimulus or with events in the nervous system, with the possible exception only of the law of association. Now-a-days it is superfluous to claim that association is solely a law of conscious events, when we are so constantly being reminded of its physiological counterpart, the conditioned reflex.