

SCIENCE

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SCIENTIFIC THOUGHT IN THE NINETEENTH CENTURY.*

It is an interesting fact that the life of our Association is almost coextensive with that nineteenth century of Christian civilization which is now drawing to a close. In intellectual, as in physical phenomena, we are tempted to overestimate the magnitude of near objects and to underestimate that of distant ones; but science and art tend to advance with accelerated velocity, and we are undoubtedly right in ranking the achievements of our age in science and its applications as far greater than those of any previous century.

When our predecessors assembled a hundred years ago to organize this Academy, they could avail themselves of no other means of transportation than those which were in use before the time of Homer. If the distances over land were too great for convenient walking, they were carried or drawn by horses. If they had occasion to cross bodies of water, they used oars or sails. We have been brought to our destination to-day by the forces of steam and electricity.

The harnessing of these mighty forces for man's use has transformed not only the modes of transportation, but the processes of production of all kinds of commodities.

* Address at the Centennial Celebration of the Connecticut Academy of Arts and Sciences, October 11, 1899.

It has wrought a revolution in the whole industrial system. The day of the small workshop is gone. The day of the great factory is come. Every phase of human life is affected by those arts which have arisen from the applications of science. Comforts and luxuries which a hundred years ago were beyond the reach of the most wealthy, are now available for the use of even the poor. Aniline dyes give to fabrics used for clothing or decoration colors beside which those of the rainbow are pale neutral tints. Sanitary science arrests the massacre of the innocents, and increases the average duration of human life. Anæsthetics and antiseptics take away from surgery its pain and its peril.

But, though our Association is an Academy of Arts and Sciences, it has, at least in its later life, devoted itself chiefly to the cultivation of pure science, leaving to other organizations the development of the applications of science. Fitly, then, our thoughts to-day dwell, not upon the vast progress of the useful arts, but upon the progress of pure science. Not the economic and the industrial, but the intellectual history of our century claims our attention.

I do not propose, in the few moments allotted to me this afternoon, to give an inventory of the important scientific discoveries of the nineteenth century. The time would not suffice therefor, even were my knowledge of the various sciences sufficiently encyclopædic to justify me in the attempt. I wish rather to call your attention to a single broad, general aspect of the intellectual history of our age. I wish to remind you in how large a degree those general ideas which make the distinction between the unscientific and the scientific view of nature have been the work of the nineteenth century.

The first of these ideas is the extension of the universe in space. The unscientific mind looks upon the celestial bodies as

mere appendages to the earth, relatively of small size, and at no very great distance. The scientific mind beholds the stellar universe stretching away, beyond measured distances whose numerical expression transcends all power of imagination, into immeasurable immensities.

The second of these ideas is the extension of the universe in time. To the unscientific mind, the universe has no history. Since it began to exist, it has existed substantially in its present condition. Among Christian peoples, until the belief was corrected by science, the Hebrew tradition of a creative week six thousand years ago was generally accepted as historic fact. If, on the other hand, unscientific minds not possessed of any supposed revelation in regard to the date of the world's origin, thought of the universe as eternal, that eternity was still conceived as an eternity of unhistoric monotony. The scientific mind sees in the present condition of the universe the monuments of a long history of progress.

The third of these ideas is the unity of the universe. To the unscientific mind the universe is a chaos. To the scientific mind it becomes a cosmos. To the unscientific mind, the processes of nature seem to be the result of forces mutually independent and often discordant. Polytheism in religion is the natural counterpart of the unscientific view of the universe. To the scientific mind, the boundless complexity of the universe is dominated by a supreme unity. One system of law, intelligible, formulable, pervades the universe, through all its measureless extension in space and time. The student of science may be theist or pantheist, atheist or agnostic; polytheist he can never be.

What then, let us ask ourselves, has been the contribution of our century to the development of these three ideas, which characterize the scientific view of nature:—the spatial extension of the universe, the his-

toric extension of the universe, and the unity of the universe.

The development of the idea of the extension of the universe in space belongs mainly to earlier times than ours. The Greek geometers acquired approximately correct notions of the size of the earth and the distance of the moon. The Copernican astronomy in the sixteenth century shifted the center of the solar system from the earth to the sun, and placed in truer perspective our view of the celestial spheres. But, though astronomy, the oldest of the sisterhood of the sciences, attained a somewhat mature development centuries ago, it has in our own century thrown new light upon the subject of the vastness of the universe. The discovery of Neptune has greatly increased the area of the solar system; the measurement of the parallax of a few of the brightest and presumably the nearest of the stars has rendered far more definite our knowledge of the magnitude of the stellar universe; and telescopes of higher magnifying power than had been used before have resolved many clusters of small and distant stars.

If the development of the idea of the spatial extension of the universe belongs mainly to an earlier period, the idea of its historic extension belongs mainly to our century. It is true, indeed, that Pythagoras and others of the ancient philosophers did not fail to recognize indications of change in the surface of the earth. And, in the beginning of the Renaissance, we find Leonardo da Vinci and others insisting that the fossils discovered in excavations in the stratified rocks were proof of the former existence of a sea teeming with marine life, where cultivated lands and populous cities had taken its place. Hutton's 'Theory of the Earth,' which in an important sense marks the beginning of modern geological theorizing, appeared in the *Edinburgh Philosophical Transactions* in

1788, but was not published as a separate work till seven years later. Not till 1815 was published William Smith's Geological Map of England, the first example of systematic stratigraphic work extended over any large area of country. To the beginning of our century belong also the classical and epoch-making researches of Cuvier upon the fossil fauna of the Paris basin. By far the larger part, therefore, of the development of geologic science, with its far-reaching revelations of continental emergence and submergence, mountain growth and decay, and evolution and extinction of successive faunas and floras, belongs to the nineteenth century. Far on into our century extended the conflict with theological conservatism, in which the elder Silliman, James L. Kingsley, and others of the early members of our Academy bore an honorable part, and which ended in the recognition, by the general public as well as by the select circle of scientific students, of an antiquity of the earth far transcending the limits allowed by venerable tradition.

To our century also belongs chiefly the development in astronomy of the idea of the history of the solar system. It is, indeed, true that, in the conception of the nebular hypothesis, Laplace, whose "Théorie de la Monde" was published in 1796, was preceded by Kant and Swedenborg; yet the credit of the discovery belongs not so much to the first conception of the idea as to its development into a thoroughly scientific theory. Our century, moreover, has added to those evidences of the nebular theory, which Laplace derived from the analogies of movement in the solar system, the evidence furnished by the spectroscope, which finds in the nebulae matter in some such condition as that from which the solar system is supposed to have been evolved.

But by far the most important contribution of this century to the intellectual life

of man is the share which it has had in developing the idea of the unity of nature. The greatest step prior to this century in the development of that idea (and probably the most important single discovery in the whole history of science) was Newton's discovery of universal gravitation two hundred years ago; but the investigations of our century have revealed, with a fullness not dreamed of before, a threefold unity in nature—a unity of substance, a unity of force, and a unity of process.

Spectrum analysis has taught us somewhat of the chemical constitution, not only of the sun, but also of the distant stars and nebulae; and has thus revealed a substantial identity of chemical constitution throughout the universe. Profoundly interesting, from this point of view, is the recent discovery, in uraninite and some other minerals, of the element helium, previously known only by its line in the spectrum of the sun. Profoundly interesting will be, if confirmed by further researches, the still more recent discovery of terrestrial coronium.

The doctrine of the conservation of energy formulates a unity of force in all physical processes. In this case, as in others, prophetic glimpses of the truth came to gifted minds in earlier times. Lord Bacon declared heat to be a species of motion. And Huyghens, in the seventeenth century, distinctly formulated the theory of light as an undulation, though the mighty influence of Newton maintained the emission theory in general acceptance for a century and a half.

When Lavoisier exploded the phlogiston theory, and laid the foundation of modern chemical philosophy, it was seen that, in every chemical change, there is a complete equation of matter. But there was in the phlogiston theory a distorted representation of a truth which the chemical theory of Lavoisier and his successors ignored. They

could give no account of the light and heat and electricity so generally associated with chemical transformations. These "imponderable agents," as they were called, believed to be material, yet so tenuous as to be destitute of weight, haunted like ghosts the workshop of the artisan and the laboratory of the scientist, wonderfully important in their effects, but utterly unintelligible in their nature. It was almost exactly at the beginning of our century that the researches of Rumford discovered the first words of the spell by which these ghosts were destined to be laid. When Rumford declared, in his interpretation of his experiments, "Anything which any insulated body or system of bodies can continue to furnish without limitation, cannot possibly be a material substance," the fate of the supposed imponderable fluid heat was sealed; but it was not till near the middle of our century that Joule completed the work of Rumford by the determination of the mechanical equivalent of heat. About the same time, Foucault's measurement of the velocity of light in air and in water afforded conclusive proof of the undulatory theory of light. In these great discoveries was laid the strong foundation for the magnificent generalization of the conservation of energy—a generalization which the sagacious intuition of Mayer and Carpenter and Le Conte at once extended beyond the realm of inorganic nature to the more subtle processes of vegetable and animal life. In this connection, I may be permitted to refer to the work of some of my colleagues, with the Atwater-Rosa calorimeter, which has given more complete experimental proof than had previously been given of the conservation of energy in the human body.

But by far the greatest of the intellectual achievements of our age has been the development of the idea of the unity of process pervading the whole history of nature. The word which sums up in itself the ex-

pression of the most characteristic and fruitful intellectual life of our age is the word evolution. The latter half of our century has been so dominated by that idea in all its thinking, that it may well be named the Age of Evolution. We may give as the date of the beginning of the new epoch the year 1858; and the Wittenberg theses of the intellectual reformation of our time were the twin papers of Darwin and Wallace, wherein was promulgated the theory of natural selection.

And yet, of course, the idea of evolution was not new, when these papers were presented to the Linnaean Society. Consciously or unconsciously, the aim of science at all times must have been to bring events that seemed isolated into a continuous development. To exclude the idea of evolution from any class of phenomena, is to exclude that class of phenomena from the realm of science. In the former half of our century, evolutionary conceptions of the history of inorganic nature had become pretty well established. The nebular hypothesis was obviously a theory of planetary evolution. The Lyellian geology, which took the place of the catastrophism of the last century, was the conception of evolution applied to the physical history of the earth.

Nor had there been wanting anticipations of evolution within the realm of biology. The author of that sublime Hebrew psalm of creation, preserved to us as the first chapter of Genesis, was in his way a good deal of an evolutionist. 'Let the earth bring forth,' 'let the waters bring forth,' are words that point to a process of growth rather than to a process of manufacture in the origination of living beings. In crude and vague forms, the idea of evolution was held by some of the Greek philosophers. Just at the beginning of our century Lamarck developed the idea of evolution into something like a scientific theory. Yet it

is no less true that the epoch of evolution in human thought began with Darwin. Manifold suggestions there were of genetic relationships between different organisms, whether organic forms were studied by the systematist or the embryologist, the geographer or the paleontologist; but each and all found the path to any credible theory of organic evolution blocked by the stubborn fact that variations in species appeared everywhere to be limited in degree, and to oscillate about a central average type, instead of becoming cumulative from generation to generation. In the Darwinian principle of natural selection, for the first time, was suggested a force, whose existence in nature could not be doubted, and whose tendency, conservative in stable environment, progressive in changing environment, would account at once for the permanence of species through long ages, and for epochs of relatively rapid change. However Darwin's work may be discredited by the exaggerations of Weismannism, however it may be minified by Neo-Lamarckians, it is the theory of natural selection which has so nearly removed the barrier in the path of evolution, impassable before, as to lead, first the scientific world, and later the world of thought in general, to a substantially unanimous belief in the derivative origin of species. Certain it is that no discovery since Newton's discovery of universal gravitation has produced so profound an effect upon the intellectual life of mankind. The tombs of Newton and Darwin lie close together in England's Valhalla, and together their names must stand as the two great epoch-making names in the history of science.

Darwin's discovery relates primarily to the origin of species by descent with modification from preëxisting species. It throws no direct light upon the question of the origin of life. But analogy is a guide that we may reasonably follow in our think-

ing, provided only we bear in mind that she is a treacherous guide and sometimes leads astray. Conclusions that rest only on analogy must be held tentatively and not dogmatically. Yet it would be an unreasonable excess of caution that would refuse to recognize the direction in which analogy points. When we trace a continuous evolution from the nebula to the dawn of life, and again a continuous evolution from the dawn of life to the varied flora and fauna of to-day, crowned as it is with glory in the appearance of man himself, we can hardly fail to accept the suggestion that the transition from the lifeless to the living was itself a process of evolution. Though the supposed instances of spontaneous generation all resolve themselves into errors of experimentation, though the power of chemical synthesis, in spite of the vast progress it has made, stops far short of the complexity of protoplasm, though we must confess ourselves unable to imagine any hypothesis for the origin of that complex apparatus which the microscope is revealing to us in the infinitesimal laboratory of the cell, are we not compelled to believe that the law of continuity has not been broken, and that a process of natural transition from the lifeless to the living may yet be within reach of human discovery?

Still further. Are we content to believe that evolution began with the nebula? Are we satisfied to assume our chemical atoms as an ultimate and inexplicable fact? Herschel and Maxwell, indeed, have reasoned, from the supposed absolute likeness of atoms of any particular element, that they bear "the stamp of a manufactured article," and must therefore be supposed to have been specially created at some definite epoch of beginning. But, when we are speaking of things of which we know as little as we know of atoms, there is logically a boundless difference between saying that we know no difference

between the atoms of hydrogen, and saying that we know there is no difference. Is it not legitimate for us to recognize here again the direction in which analogy points, and to ask whether those fundamental units of physical nature, the atoms themselves, may not be products of evolution? Thus analogy suggests to us the question, whether there is any beginning of the series of evolutionary changes which we see stretching backward into the remote past; whether the nebulae from which systems have been evolved were not themselves evolved; whether existing forms of matter were not evolved from other forms that we know not; whether creative Power and creative Intelligence have not been eternally immanent in an eternal universe. I cannot help thinking that theology may fitly welcome such a suggestion, as relieving it from the incongruous notion of a benevolent Deity spending an eternity in solitude and idleness. The contemplation of his own attributes might seem a fitting employment for a Hindoo Brahm. It hardly fits the character of the Heavenly Father, of whom we are told that he 'worketh hitherto.'

In the last suggestion I have ventured outside the realm of science. But most men are not so constituted that they can carry their scientific and their philosophical and religious beliefs in compartments separated by thought-proof bulkheads. Scientific and philosophic and religious thought, in the individual and in the race, must act and react upon each other. It was, therefore, inevitable that our century of scientific progress should disturb the religious beliefs of men. When conceptions of the cosmos with which religious beliefs had been associated, were rudely shattered, it was inevitable that those religious beliefs themselves should seem to be imperilled. And so, in the early years of the century, it was said, if the world is more than six thousand years old, the Bible is a fraud,

and the Christian religion a dream. And later, it was said, if physical and vital forces are correlated with each other, there is no soul, no distinction of right and wrong, and no immortality. And again it was said, if species originate by evolution, and not by special creation, there is no God. So it had been said centuries before, if the earth revolves around the sun, Christian faith must be abandoned as a superstition. But in the nineteenth century, as in the sixteenth, the scientific conclusions won their way to universal acceptance, and Christian faith survived. It showed a plasticity which enabled it to adapt itself to the changing environment. The magically inerrant Bible may be abandoned, and leave intact the faith of the church in a divine revelation. The correlation of forces acting in the human cerebrum with those of inorganic nature may be freely admitted; and yet we may hold that there are other forms of causation in the universe than physical energy, and that the inexpugnable belief of moral responsibility is more valid than the strongest induction. The 'carpenter God' of the older natural theology may vanish from a universe, which we have come to regard as a growth and not a building; but there remains the immanent Intelligence

" Whose dwelling is the light of setting suns,
And the round ocean, and the living air,
And the blue sky, and in the mind of man;"—

the God in whom 'we live and move and have our being.'

The church has learned wisdom. The persecution of Galileo is not likely to be repeated, nor even the milder forms of persecution which assailed the geologists at the beginning, and the evolutionists in the middle, of our century. And science, too, has learned something. In all its wealth of discovery, it recognizes more clearly than ever before the fathomless

abysses of the unknown and unknowable. It stands with unsandaled feet in the presence of mysteries that transcend human thought. Religion never so tolerant. Science never so reverent. Nearer than ever before seems the time when all souls that are loyal to truth and goodness shall find fellowship in freedom of faith and in service of love.

WM. NORTH RICE.

*RESULTS OF THE SECOND BOTTEGÒ EXPEDITION INTO EASTERN AFRICA.**

UNDER the auspices of the Italian Geographical Society, whose President signs the preface, the survivors of the Second Bottegò Expedition into Eastern Africa have prepared and published a narrative of their arduous journey, and an account of the results achieved at the cost of two valuable lives. The volume is well written and profusely illustrated—it is, moreover, accompanied by a series of clearly drawn maps of the country traversed, much of which had been previously unvisited by European explorers.

On his second expedition Vittorio Bottegò, accompanied by three valiant assistants—Lamberto Vannutelli, Lieutenant in the Royal Navy; Carlo Citerni, of the Italian Army, and Dr. Maurizio Sacchi, left Naples on the 3d of June, 1895, and reached Brava on the Southern Somali coast on the 1st of October of that year. Ten days later the explorers marched out of Brava with a caravan of 250 Ascaris, and on November 18th reached the outskirts of Lugh, an important emporium of trade in Southern Somaliland, situated on the River Juba in about 3° north latitude, which had been visited by Bottegò on his first expedition. Lugh, it was found was

* L'Omo. Viaggio di esplorazione nell' Africa Orientale narrato da L. Vannutelli e C. Citerni. Sotto gli auspici della Società Geographica Italiana. Milano, 1899.