THE

BIBLIOTHECA SACRA.

ARTICLE I.

TWENTY-FIVE YEARS OF SCIENTIFIC PROGRESS.[1]

BY PROFESSOR WILLIAM NORTH RICE, MIDDLETOWN, CONN.

I PROPOSE to call your attention to a hasty review ot some phases of the progress made in Science, and particularly in the sciences of Biology and Geology, in the last quarter-century. If I seem unduly egotistical in taking for my theme exactly the period covered by my own professional career, and in beginning my remarks by an autobiographic reference, you must pardon the offence as being due to the elation experienced by reason of the honor, alike unexpected and undeserved, which you have conferred upon me in calling me to the presidential chair.

When the next season of College Commencements comes around, it will be exactly a quarter of a century since a little group of students, most of whom are now members of this Society, were assembled in the Biological Laboratory of the Sheffield Scientific School. They had just been reading their graduating theses. The subjects of one of those theses was the "Darwinian Theory of the Origin of Species;"[2] and the writer thereof had, to his own satisfaction

[1] Address of the President, American Society of Naturalists, December, 1891.

[2] Published in New Englander, October, 1867.

at least, refuted that famous theory. A recent graduate of the school who chanced to be present, showed the young men a photograph of Darwin. It was the first time any of them had seen Darwin's portrait; and, as they looked upon that countenance, in which no admiration for the man's genius and character can prevent the impartial observer from recognizing a certain likeness to a gorilla, and contrasted it with the refined and spirituelle face of their great master, whom they regarded with a reverence almost approaching adoration, one of the young men remarked, "You need only compare the faces of Darwin and Dana to know why one of them is an evolutionist and the other is not." Little did those young men know that, in a few years, not only they themselves, but their great master, would join the ranks of the evolutionists.

But those young men were not so stupid nor so ultra-conservative as you might suppose. In 1867 Darwin was in the minority. It was then only nine years since the twin papers of Darwin and Wallace had been read before the Linnæan Society; and the epoch-making book, "The Origin of Species," was then only eight years old. The inertia of mind is as significant a force as the inertia of matter; and in those early years the doctrine of Evolution made converts but slowly. In England, Hooker, Huxley, Lubbock, and (with some hesitation) Lyell had already placed themselves on the side of Evolution. Owen occupied a somewhat anomalous position, believing in Evolution, but not believing in any particular theory of Evolution. Natural Selection he claimed to be no discovery; but he claimed that if it was any discovery, he made it himself. Even in England the mass of intelligent public opinion, and probably even of scientific opinion, was adverse to Evolution. In Germany, Hæckel was already leading the mighty host marching with almost fanatical zeal to the war-cry, "Great is Evolution, and Darwin is its prophet;" finding in Darwinism not only their science, but their philosophy, their politics, and their religion. In this country, Evolution found one mighty supporter in Asa Gray, whom, at least now that he has finished his earthly labors, it is no disparagement to others to call the most profoundly philosophic mind among American naturalists. But Gray stood well-nigh alone. The two other great philosophical naturalists who then adorned this country, and one of whom is still spared to us, Agassiz and Dana, were both anti-evolutionists. It was five years later than the date of which we are speaking, that Darwin was rejected as a candidate for membership in the French Academy, by a vote of more than two-thirds; and a distinguished Academician, in giving the reasons for Darwin's rejection, pronounced the "Origin of Species" "a mass of assertions and absolutely gratuitous hypotheses, often evidently fallacious." Elie de Beaumont's oft-quoted phrase, "science mousseuse," is fitly expressive of the contempt with which Darwin's views were regarded even by many scientific men. Nemesis has dealt rather sternly with the author of that phrase; for it has come to pass that he is chiefly remembered for two things—his blasphemy against the name of Darwin, and his origination of a theory in regard to mountain elevation which is as cumbersome, false, and sterile, as the theory which he held up to ridicule is simple, true, and fruitful.

The revolution of opinion upon the subject of Evolution is certainly the great feature of the history of the last quarter-century. The fingers of one hand will now more than suffice to count all anti-evolutionists who are competent to have an opinion on the subject. The principle of Natural Selection is universally acknowledged to be a most important discovery; though naturalists of the neo-Lamarckian school think its importance has been somewhat overrated, while the ultra-Darwinian school claim more for Natural Selection than Darwin claimed himself. Not a few of us, indeed, believe that the departures in both directions from Darwin's positions have been for the worse;—that, in maintaining the adequacy of Natural Selection to evolve new species by means of fortuitous variation, while conceding nevertheless the possibility of a more direct influence of environment through inheritance of the effects of use and disuse and of other acquired variations, the views of Darwin himself still remain the most accordant with all known facts. But, whatever differences of opinion there may be in regard to the relative efficiency of Natural Selection and other evolutionary forces, all naturalists of the present day would unite in recognizing Darwin as the one great epoch-making name in the history of science since that of Sir Isaac Newton. Together lie the mortal remains of these two great men in Westminster Abbey; and together their names will stand in the history of science—Newton, whose conception of Universal Gravitation gave unity to inorganic nature; Darwin, whose conception of Natural Selection gave unity to organic nature. It is no extravagant praise of Darwin's work to predict that future historians of the intellectual progress of our race will recognize the publication of the "Origin of Species" as the great event in the intellectual history of the nineteenth century.

The importance of the intellectual movement which commenced with the publication of the "Origin of Species" depends not alone or chiefly upon the fact that a single great truth in biological science has been established, but upon the fact that the effect of that truth has been to revolutionize scientific thought in general. The whole character of biological science has been changed. From the condition of a merely classificatory science, it has passed into that of a dynamical science. In 1857, Darwin, writing to Wallace, lamented that "very few naturalists care for anything beyond the mere description of species." So completely has the spirit of biological investigation been changed, that at present, fascinated by the countless questions which the evolutionary view of nature is presenting to our attention on every hand, naturalists are in danger even of despising and neglecting the humble but necessary labors of systematic Botany and Zoölogy.

Nor is it alone in the realm of biological science that the influence of Darwin's great discovery has been felt. There is no department of thought, however remote from the technical study of Biology, which has not felt the profound influence of the new idea. The thought which inspires and characterizes the whole intellectual life of the closing quarter of the nineteenth century, finds its expression in the word Evolution.

Twenty-five years ago Spontaneous Generation was a burning question. The publication of Pasteur's series of papers on fermentation commenced in 1857, and his first paper on febrine was published in 1865. No one doubts to-day that Pasteur's views in regard to the origin of the lowest organisms were right; but then numerous skilful and conscientious observers were experimenting, under what seemed to be similar conditions, with conflicting results. At that time Pasteur's views were hotly contested in his own country by Pouchet. Child, in 1865, had announced the appearance of organisms, after what seemed to be sufficient precautions, for the destruction of germs in the material experimented upon, and the exclusion of atmospheric germs; and claimed that Pasteur's negative results were due to the fact that the latter had employed magnifying powers of no more than 350 diameters, while he himself had used powers of 1,500 diameters. In our own country, Wyman's two series of experiments were published respectively in 1862 and 1867. Amid the conflicting experiments, the general results appeared to be, that, the higher the temperature to which the fluids were subjected, the longer the time in which they were exposed to that high temperature, and the less the quantity of free oxygen present, the less was the likelihood of the appearance of organisms. The facts appeared then ambiguous; for extremely high temperature, prolonged cooking, and absence of free oxygen, seemed inimical, alike to the development of pre-existent germs, and to the initiation of the chemical processes by which it might be supposed new organisms were produced from the decay of old ones. The whole subject is plain enough now. The conflicting results which puzzled us then, in so far as they were not due to mere errors in experimentation, prove only the extraordinary tenacity of life possessed by the germs of low organisms under certain exceptional conditions. But twenty-five years ago it was not so plain.

The curious change which has passed over our judgment of the relative probability of the theories of spontaneous generation and specific evolution is well shown by the argument for evolution contained in a book published a short time before the date of which we are speaking,—a book which then attracted considerable attention, though now well-nigh forgotten,—H. J. Clark's "Mind in Nature." Accepting spontaneous generation, as proved by the experiments of Wyman, the author proceeded to argue that, if there is a natural transition from non-living to living matter, there must be, *a fortiori*, a natural transition from the lower to the higher forms of life.

Of course, in those days when we were puzzling over the question of spontaneous generation, we could not dream of that immense development of knowledge of the lowest organisms and their manifold biological relations which was destined to create the new science of Bacteriology. Though Pasteur had commenced the investigation of febrine, the germ theory of disease, in any comprehensive sense, was yet in the future. The contributions from that source, alike to theoretical pathology and to practical therapeutics and hygiene, were utterly undreamed of. The saving of life by antiseptic surgery, the arrest of the annual massacre of the innocents in the summer heat of our cities by the simple process of the sterilization of milk, the protection from many infectious diseases to be gained by the cooking of impure water, were among the gifts which science had yet in reserve for suffering humanity.

The twenty-five years which we have under review have seen a great change in our notions of Zoölogical classification. Twenty-five years ago Agassiz's "Essay on Classification" was widely accepted as a true and profound statement of the principles of taxonomy. A doctrine continually insisted upon in that work was, that the groups of a natural classification were "instituted by the Divine Intelligence as the categories of his mode of thinking." It is difficult to understand how that proposition was ever supposed to be of any scientific significance, though it may be very good philosophy and theology. It apparently amounts to nothing more than is implied in all theistic philosophy. If organic beings, in common with other natural objects, are the work of an omniscient Creator, it is sufficiently obvious that the relations of likeness and unlikeness between different organic beings, which are the basis of classification, must have been known to the Creator before they were discovered by any naturalist. In Systematic Zoölogy, as in every other science, and in one science no more than in any other, the devoted student may believe with Kepler that he is thinking God's thoughts after him. From the standpoint of pure science, the dictum of Agassiz appears utterly irrelevant. The Creator has certainly not seen fit to reveal what characters he regards as of the greatest taxonomic importance; and the judgment which any individual naturalist may form, as to the relative importance of the various likenesses and unlikenesses which exist between different animals, will be entirely independent of his theological opinions.

But Agassiz seemed to think that the categories of thought in the Divine Mind had been revealed to himself, as if by plenary inspiration. The division of the animal kingdom into *Vertebrata*, *Articulata*, *Mollusca*, and *Radiata* was not *a* classification, but *the* classification. There were absolutely four types in the animal kingdom, and there could be no others. The majority of naturalists had already modified the Cuvierian list of subkingdoms at least by the addition of *Protozoa;* but for this departure from the faith Agassiz had no toleration. The *Protozoa*, he maintained, were a heterogeneous assemblage, some of them probably larval forms of higher animals, some of them too little understood for the recognition of their true relations, some of them probably vegetable.

It was maintained by Agassiz, and, at least in this country, the doctrine was generally accepted, that all homologies were limited by the boundaries of the Cuvierian subkingdoms. The spheromere of the radiate, the sac of the mollusc, the arthromere of the articulate, and the vertebra of the vertebrate, were constructed on plans so absolutely and radically dissimilar that no part of any one of these structures could be homologous with any part of any other. This doctrine of the limitation of homologies within the bounds of particular subkingdoms was one of the leading arguments of the thesis against the Darwinian theory to which I have referred. Since no part or organ in an animal of one subkingdom could be homologous with any part or organ in an animal of any other subkingdom, any genetic transition across the boundaries of the subkingdoms was entirely out of the question. It was indeed about this time —1866 or 1867—that Kowalevsky began the publication of those embryological researches which so clearly established the homology of the layers of the blastoderm in all *Metazoa;* but neither the writer of the thesis nor his companions had seen or heard of Kowalevsky's papers, and most of them were still unpublished. Kowalevsky's discovery was of course fatal to the Agassizian doctrine of the limitation of homologies within the boundaries of the respective subkingdoms, and to all anti-evolutionist arguments derived from that doctrine. It prepared the way for Hæckel's *Gastræa* theory in 1874, and for other similar speculations in regard to the common ancestor of the *Metazoa*.

Twenty-five years ago the doctrine was by no means as clearly recognized as at present, that morphological characters must dominate over all others in natural history classifications. Indeed, the classifications then in vogue were very largely physiological. The *Merostomata* still held an unquestioned place among *Crustacea*, for were they not water-breathing articulates? And the arachnids still remained among insects, for were they not air-breathing articulates? The division of vertebrates into cold-blooded and warm-blooded, *Hæmatocrya* and *Hæmatotherma*, as given in Owen's "Anatomy of Vertebrates," the first volume of which was published in 1866, was then generally accepted. The *Amphibia* were only ordinally separated from the true reptiles, while a great gap was supposed to exist between reptiles and birds. Our friend Dr. Baur's proposition to regard the birds as a suborder of dinosaurs (which still seems to many of us rather extreme) would then have seemed as absurd as to put butterflies among trematode worms. Lampreys and lancelets still retained their place among fishes, for were they not oviparous, cold-blooded, water-breathing vertebrates? Kowalevsky's discovery of the notochord in tunicate embryos startled the world in 1867. Before that date no close relationship between tunicates and vertebrates had been dreamed of. A tunicate seemed to us, in fact, not very different from a shell-less lamellibranch. It seemed very natural to compare the mouth of the tunicate with the orifice of the incurrent siphon in the lamellibranch, the lattice-work of the pharyngeal wall in the tunicate with the gills of the lamellibranch, the aboral orifice of the pharynx in the tunicate with the mouth of the lamellibranch, the atrium of the tunicate with the cloacal region of the lamellibranch, and the atrial orifice of the tunicate with the orifice of the excurrent siphon in the lamellibranch. In both cases, the water, which supplies the animal alike with oxygen and with food, filters through the respiratory lattice-work; and the fact that the parts are not in exactly the same relative position suggested no doubts in regard to the soundness of the rather physiological homologizing which was then in vogue.

Not only physiological characters, but even such purely superficial characters as those relating to habits and mode of life, were freely used in the classifications which were in vogue twenty-five years ago. Witness the common classification of birds into perchers, walkers, and swimmers; or another division of birds, regarded at that time with considerable favor, into *Altrices* and *Præcoces*, according as the young are fed by the parents, or are able to seek food for themselves. It was about that period that one of the most philosophical of naturalists maintained for a time that the distinction between man and apes, in that the anterior limbs are almost exclusively organs of prehension in the former, while in the latter their chief function is locomotive, was parallel to the distinction between hexapods and arachnids, in that the homologue of the labium of hexapods appears as the first pair of legs in the arachnids.

It is needless to comment on the light which Evolution has thrown on taxonomy. I do not believe, indeed, that we can have a strictly genealogical classification. The degree of distinctness between groups depends not upon the number of generations intervening between them and a common ancestry, but upon the amount of modification, and very largely upon the amount of extinction, which has taken place. Groups which are really very near of kin, may in some cases seem to be very widely separated by reason of an unusually complete extinction of intermediate forms; while, in other cases, groups whose common ancestry is really very remote, may be bound together in our classifications by the survival of large numbers of gradational forms. Moreover, we must recognize that evolution may be convergent, as well as divergent. The twigs which are nearest together on the tree are not necessarily derived from the same bough. Polyphyletic groups, as Hæckel has called them, are certainly possible, and probably many such groups exist. But, while a classification cannot be strictly genealogical, the genealogical idea is nevertheless of vast importance in classification. The doctrine of evolution has led us to a clear recognition of that truth, of which the most philosophic naturalists have caught glimpses ever since the time of Cuvier, though oftentimes their vision was only like that of him who saw "men as trees walking,"—the truth that morphological characters must dominate in any true system of classification. Physiological characters may be quickly acquired and quickly lost, in the struggle for life amid a continually changing environment. Plans of structure, once established, are maintained by heredity acting with accumulating force through countless generations.

The classification of Flowering Plants has undergone, during the last twenty-five years, less modification than that of animals; but much progress has been made in reducing to order the mob of cryptogams. The physiological classification of the lower cryptogams into *Algæ* and *Fungi*—a classification which, like many other purely artificial ones, is convenient to retain for certain purposes—has given place in Systematic Botany to classifications founded upon morphological characters.

The period which we are considering has been marked by great progress in our knowledge of the mutual relations of plants and animals, including such subjects as commensalism and parasitism. Schwendener's discovery of the composite nature of lichens, that most striking example of symbiosis in the vegetable kingdom, was not announced until

1869. The subject of the fertilization of plants by insects is one of those whose study belongs almost exclusively to the period under consideration. Sprengel, indeed, had given to the world much of accurate observation and sound theory, though with not a little admixture of what was merely fanciful, as early as 1793; and Kölreuter thirty years earlier had anticipated some of the same views. Yet, in an important sense, the study of these beautiful adaptations may be said to have begun with Darwin's work on the "Fertilization of Orchids," which was published in 1862. Darwin's investigations on insectivorous plants—those organisms which so curiously break down one of the hard-and-fast lines supposed to exist between plants and animals—had been commenced in 1860, but were still unpublished in 1867. At that date, very little had been published on the subject; and some of that little was suffering a deserved, and the rest an undeserved, neglect. The subject is one of those territories whose conquest by science belongs to the last quarter-century.

Our knowledge of the minute structure of animals and plants has made immense progress during the period under consideration, by means of improved histological methods. There is a prodigious difference between the slices cut by Valentin's two-bladed knife, or the chips cut off by a double-edged scalpel (which, it might be hoped, would be thin enough on the edges in some places to show something), and the serial sections made by a modern automatic microtome. The methods of staining, by which various histological elements are so exquisitely differentiated from each other, belong almost exclusively to the past quarter-century.

In Physiology, the period under review has been signalized by the advance from merely qualitative observations to exact quantitative measurements. Eminently characteristic of the past quarter-century has been the work done by the various instruments for the automatic recording of physiological processes—the cardiograph, the sphygmograph, the plethysmograph, the myograph, and various other "graphs" which my knowledge of Physiology does not suffice even to name.

Immense progress has been made also in our knowledge of the relations of organisms to space and time. Wallace's Line, indeed, had been discovered some years before the commencement of the period under review; and Sclater had already, in 1857, proposed the division of the globe into those regions which are still very commonly accepted by writers on zoölogical geography. But, at the beginning of this quarter-century, Wallace's noble volumes on "Geographical Distribution" were yet unpublished. The support which the study of geographical distribution was destined to give to evolution, and the wealth of meaning which evolution was to throw into the facts of geographical distribution, were then unappreciated. Twenty-five years ago, not a few naturalists accepted the doctrine of Agassiz, that a species was represented at the time of its original creation by about as large a number of individuals as were destined to exist at any subsequent time; and that thus the geographical range of a species, as well as its morphological and physiological characters, was defined in the primal act of creation: though those extremely supernaturalistic views could not be considered as scientific orthodoxy even then. In one important respect, the extreme supernaturalism of Agassiz was a preparation for the naturalism of Darwin. In denying the existence of any tie between the individuals of a species other than that which exists between the species of a genus or the genera of a family, Agassiz was unconsciously preparing men's minds for the reception of the doctrine that the tie is indeed the same in both cases, being in both cases the simple and obvious one of consanguinity.

Within the last quarter-century, zoölogical exploration has not only enriched our knowledge of continental and littoral faunas, but has discovered a new world of life in the abysses of the ocean. In 1867, very little was known of deep-sea life. A few sporadic observations, such as that of Fleeming Jenkin, in 1860, hauling up a telegraph cable between Africa and Sardinia, and finding *Caryophyllia* growing upon it at the depth of twelve hundred fathoms, sufficed, or might have sufficed, to prove the falsity of the traditional notion of the absence of life in abyssal depths. But such sporadic observations attracted less attention than they deserved, and as yet no systematic exploration of the deep sea had been undertaken. Altogether in the future were those magnificent researches which were destined to render illustrious in the history of science the names of the Lightning, the Porcupine, and the Challenger, the Bibb, the Hassler, the Blake, and the Albatross, the Talisman, the Sophia, and the Josephine.

Twenty-five years ago the groups of organisms represented in a fossil condition were separated from each other by gaps which seemed in many cases impassable chasms. The imperfection of the geological record was by no means duly appreciated, although the principle was an inevitable corollary of the Lyellian Geology. Agassiz, with that kind of prophetic insight which gave him, as from some Pisgah height, broad and far-reaching views of territories of truth which he could never enter into and possess, had pointed out the striking coincidences between the series afforded by embryonic development, paleontological succession, and systematic rank; but neither he nor his followers recognized what now seems the simple and obvious meaning of those generalizations. In regard to the absence of connecting links between fossil forms, Darwin himself remarked, "This, perhaps, is the most serious and obvious objection which can be urged against my theory." With so many and so wide gaps yet unfilled, and with the imperfection of the geological record not as yet duly appreciated, it is not surprising that most of the leading paleontologists twenty-five years ago conceived the facts of their science to be adverse to the theory of Evolution.

The quarter-century has recorded immense progress in filling those gaps. One feather of *Archæopteryx* was discovered as early as 1860, and the headless specimen now in the British Museum was discovered a year later. But twenty-five years ago *Hesperornis* and *Ichthyornis* were as yet unknown, and *Archæopteryx* was not yet known or even suspected to have possessed teeth. The dinosaurs were imperfectly known, and their close relationship with birds was not appreciated. Leidy, Cope, and Huxley had, indeed, already called attention to the disparity between the anterior and posterior limbs of the dinosaurs, and drawn the correct inference in regard to their bipedal or semi-bipedal mode of locomotion. But the earlier notions of von Meyer and Owen were still generally accepted. Hawkins's restoration of *Iguanodon*, with much the general aspect of a hippopotamus, was still generally accepted as correct. *Hipparion* was known, but not the splendid series of forms illustrating the genealogy of the horse both in Europe and in America. Nothing was known of those series of fossil forms revealing the probable pedigree of so many genera of living mammals, which have come from the exhaustless treasures of the Tertiary lacustrine beds of the western United States, and whose discovery and investigation have been in so large part the work of our honored associates, Leidy, Marsh, Cope, Osborn, and Scott. Owen had described a tooth of *Coryphodon* as early as 1846, but a score of years later the peculiar character of its feet was still unsuspected. Nothing was known of the early stages of the development of the ungulate type, as illustrated in the *Condylarthra* and the *Amblypoda*.

One noteworthy result of recent work in Paleontology has been to carry many groups back to a much earlier period in geological time. Twenty-five years ago we knew no insects earlier than the Devonian, no fishes earlier than the Ludlow beds just on the boundary between Silurian and Devonian.

Lyell's "Antiquity of Man" was published in 1863, and in 1867 the question of the time of man's origin was one of the burning questions. The co-existence of man with the mammoth and cave bear was not yet generally admitted, though it was a score of years or more since the beginning of Boucher de Perthes's discoveries in the gravels of the Somme Valley, and though Schmerling's investigations of the Belgian caves were of still earlier date. The man who doubts to-day the co-existence of man with the mammoth and the cave bear, is not an antagonist to be argued with, but an ignoramus to be sent to school; and certainly no scientist at present would dream of limiting the age of man to anything like the six thousand years of tradition. There is, nevertheless, at present a decided tendency to recede from Lyell's extreme claims in regard to the date of the origin of man. Some of the animals now extinct may have survived to a later date than was formerly supposed.

The two volumes of the tenth edition of Lyell's "Principles of Geology" appeared respectively in 1867 and 1868. The discussion of the Darwinian theory contained in the second volume was therefore not before the public at the date from which we have commenced our survey, though that discussion had been anticipated by a somewhat more qualified statement of the same views in the work on the "Antiquity of Man."

But Lyell was in truth the forerunner of Darwin; and would have been no less so, even if he had failed himself to recognize his mission, and to welcome the new views for which he had done so much to prepare men's minds. The triumph of Uniformitarianism over Catastrophism in the explanation of the inorganic history of the globe prepared the way for a belief in organic Evolution, since no Catastrophism could be so catastrophic as the notion of the origin of species by direct creation.

The extreme Uniformitarianism of Lyell not only favored the theory of Evolution, by its general principle of admitting no causes as having acted in the past save such as could be traced in the present; but favored especially a purely Darwinian form of the theory of Evolution, by making geological time extremely long. It may be that what most of us are now disposed to regard as the error of Lyell's views was indirectly favorable to the progress of truth, by making some of the geological difficulties in the way of the origin of species by natural selection seem less than they really were. Most of us at present are disposed vastly to reduce the limitless æons of geological time demanded by the Lyellian Geology of twenty-five years ago. Discussing, in 1867, Croll's theory of the cause of the glacial period, Lyell held that, if the glacial period was caused by an epoch of extreme eccentricity in the earth's orbit, it must have occurred in the epoch of great eccentricity which culminated about 850,000 years ago, rather than in that which culminated about 210,000 years ago. The improbability of the glacial epoch having been as ancient as even the later of those two epochs of high eccentricity is to most geologists to-day a strong reason for the rejection of Croll's theory.

The movement of the human mind in the progress of science is by no means a continuous and steady advance towards the truth. Theories may for considerable periods of time seem to be growing increasingly probable, and yet may ultimately be disproved. When the individual mind, or the collective mind of humanity, gets hold of a new idea, it tends to run to extremes. Inertia belongs to bodies in motion, as truly as to bodies at rest; and the mind possessed of a new idea displays an inertia of progress as irrational as the inertia of conservatism. The mind swings like a pendulum from one extreme to another, and in some cases a number of oscillations are required before a permanent resting-place is found. These oscillations of opinion are more conspicuous in some domains of thought than in others, being more strongly developed in proportion as observation is qualitative rather than quantitative, and in proportion as reasoning is inductive rather than demonstrative. We have already noticed one remarkable oscillation of this sort in biological science. Twenty-five years ago the doctrine of Spontaneous Generation seemed to be growing in favor, under the influence of the general tendency to find an evolutionary explanation for every class of phenomena. But the tide which then seemed flowing, has completely ebbed. The history of Geology in the last quarter-century presents a number of interesting examples of this oscillatory movement. Possibly the stimulation of the imagination by the contemplation of immeasurable magnitudes of forces and of times may render the opinions of geologists liable to this oscillatory movement in somewhat greater degree than those of some of their scientific brethren.

Two such examples of oscillation in geological opinion have already been mentioned. Twenty-five years ago the extreme Uniformitarianism of Lyell, with its slow processes and immeasurable times, was thoroughly in the ascendant. From that position we have certainly receded. Geological opinion to-day is neither Uniformitarian nor Catastrophist. Croll's eccentricity theory of the glacial period, proposed in 1864, seemed in 1867 decidedly coming into favor. Lyell, in his tenth edition, treated it with decided approval, though not committing himself to its acceptance. The theory was a fascinating one, as linking in a new and interesting relation the sciences of Astronomy and Geology, and as giving to Geology somewhat of the chronological definiteness which had belonged exclusively to its sister science. The theory, moreover, was immensely convenient, for we had not then, as, alas! we have not now, any thoroughly satisfactory geographical theory to account for the tremendous climatic mutations of Cenozoic time. But the tide seems to have turned, partly because, as already indicated, geological evidence shows that the glacial period was more recent than the latest epoch of high eccentricity; partly because it is very doubtful whether a condition of high eccentricity would tend to glaciation. A high eccentricity affects both the relative duration and the intensity of the seasons; but, as regards glaciation, the two conditions thus established tend to antagonize each other. A long winter tends to glaciation of the hemisphere whose winter falls in aphelion, but the hot summer tends to counteract this effect. The cool summer would favor accumulation of ice in the hemisphere whose summer is in aphelion, but the shortness of the winter diminishes the amount of snow.

Lyell followed Hutton in making the changes of continent and ocean perfectly kaleidoscopic, only Lyell differed from his predecessor in making the movements of elevation and subsidence involved in the change prodigiously slow. The reader of Darwin's "Letters" will remember his half-comic, half-pathetic protest, in a letter to Lyell, that the great geologist and his "disciples in a slow and creeping manner beat all the old catastrophists who ever lived." Twenty-five years ago, this doctrine of the kaleidoscopic interchange of continent and ocean was probably accepted by the majority of geologists. It finds expression in those lines of Tennyson—

"There rolls the deep where grew the tree.
O earth! what changes hast thou seen!
Where now the long street roars, hath been
The stillness of the central sea."

A score of years earlier, in 1846, Dana had announced the opposite doctrine of the permanence of continent and ocean; and he has lived to see the opinion which he advocated in the beginning of his geological career win its way to almost universal adoption. Apart from any theoretical views on the still doubtful subject of the mode of the earth's cooling, and the constitution of the earth's interior, the doctrine of the permanence of continents and oceans is supported by three important lines of evidence. The sedimentary formations which cover the greater part of the continental areas, have, almost without exception, originated in shallow waters, even chalk being no longer supposed to have been deposited in oceanic depths. The oceanic islands are nearly all volcanic. The boundaries of the range of various groups of plants and animals coincide with the present areas of deep sea. But apparently the pendulum has swung too far in this direction, and we must go back part of the way toward Lyell's views. There appear to be exceptions to all the generalizations which have been cited as favoring the doctrine of permanence of continents and oceans. Some stratified formations have been formed in deep water; some oceanic islands are not volcanic; and, while the present areas of deep sea form the boundaries of the range of many groups of organisms, and particularly of those groups which belong chiefly or exclusively to Cenozoic and recent times, the same boundaries do not hold for the organisms of earlier geological periods, or even for the existing representatives of groups of ancient origin. The distribution of the *Glossopteris* flora, in the Carboniferous period, in South Africa, India, and Australia, indicates an arrangement of continents and oceans widely different from that which now exists, and the hypothesis of Gondwana-land seems likely to come into general acceptance. It seems likely that our ultimate resting-place on the question of the permanence of continent and ocean will be somewhat intermediate between the positions of Lyell and Dana, but nearer doubtless to the latter than to the former.

Ramsay's paper "On the Glacial Origin of Certain Lakes" was published in 1862; and the past quarter-century has witnessed the rise, culmination, and decline of a glacial period in the explanation of the origin of lakes. Some writers have carried the theory to so extreme a length as to make the great lakes of our Canadian frontier exclusively or chiefly the results of glacial erosion. But the climate has ameliorated, and the theory of glacial erosion has melted into more moderate proportions.

Twenty-five years ago the Darwin-Dana theory of the origin of barrier reefs and atolls by subsidence, stood, as it had stood for a score of years before, almost unquestioned; but, within the past two decades, we have seen the rise, and, I think I may say, the decline, of a formidable rival. Murray's theory of the formation of atolls, by the more rapid growth of the corals at the periphery of the shoal upon which they are growing, the gradual extension of the reef upon a foundation formed by a talus of blocks of coral rock, and the widening and deepening of the lagoon by solution, seemed to many so complete and satisfactory an explanation of facts as to render unnecessary the hypothesis of a vast subsidence of the oceanic bottom. The Duke of Argyll, who, as King James said of Lord Bacon, "writes of learning like a Lord Chancellor," made the assumption that the subsidence theory had been certainly disproved the basis of a wholesale charge of dishonesty against scientific men, alleging that there had been a conspiracy to suppress the new views, because scientific men were unwilling to admit the fallibility of their idol, Darwin. But, in fact, the simple reason why there has been no general celebration of the funeral of the Darwin-Dana theory is, that it is not dead. The renewed study of the subject has indeed somewhat modified, but has not disproved, the doctrines taught by those two great masters. It is, indeed, true, that an atoll may be formed without subsidence. It is none the less immensely probable that the great number of atolls in the Indian and Pacific Oceans do owe their origin to a vast subsidence of the ocean bottom. It is a very significant fact that, whereas Archibald Geikie, in the first edition of his "Class-Book of Geology," published in 1886, gave only the Murray theory for the explanation of atolls, completely ignoring the Darwin-Dana theory, he states both theories in his second edition, published four years later, expressing no preference between them.

The year 1867 is important in the history of American Geology, as being the date of the beginning of geological exploration under the auspices of the National Government. Previously to that time, geological work had been carried on only incidentally, in connection with expeditions undertaken for some other object, as in the case of the Pacific Railroad Explorations and the Mexican Boundary Survey. In these and other expeditions undertaken by the government previously to 1867, the place of geology was, as Clarence King has well expressed it, only that of a camp-follower. Since 1867, we have had the energetic explorations and the elaborate reports of the Survey of the Territories, the Survey of the Fortieth Parallel, the Survey West of the One Hundredth Meridian, and the Survey of the Rocky Mountain Region; and now, on still larger scale, and with still richer results, the United States Geological Survey. Among the contributions which these Surveys have given to geological science, may be mentioned the recognition and discussion of laccolites,—a new type of igneous eruptions,—the revelation of the history of Lakes Bonneville and Lahontan, the study of the wondrous canyon system of the Colorado and its tributaries, and the investigation of the complicated orogenic movements of the Rocky Mountains.

It was not in vain that the group of brilliant geologists whose names are associated with the history of these Sur veys studied a region in which the topographical features are developed with a largeness of scale and a simplicity of structure unparalleled elsewhere in the world. The share which different nations have taken in the development of geological science, is dependent not alone upon the genius of individual workers, but in large measure upon the peculiar geological conditions of the various countries in which they have worked. It was in the presence of the varied mineral wealth of the Harz Mountains that Werner laid the foundations of Mineralogy and Lithology. The magnificent display alike of igneous and of aqueous agencies in the Highlands of Scotland helped to guide Hutton to those theoretical views which were the beginning of modern Dynamical Geology. The remarkable completeness with which, in so small an area, the English series of formations is developed, enabled William Smith to lay the foundations of Stratigraphical Geology more satisfactorily than would probably have been practicable in any other country in the world. The wealth of vertebrate fossils in the Paris Basin gave opportunity for Cuvier to create the science of Paleontology. The distinctive contribution of the United States to geological science seems to be the theory of topographic evolution, including the distinction of antecedent, consequent, and superimposed drainage, and the doctrine of base-levels. It is true that a beginning had been made in this line of work long before. As early as 1847 Ramsay had perceived that the summits of a number of the Welsh mountains lie in an inclined plane extending from Snowdon down to the sea, and had formulated the conception of plains of marine denudation. Jukes, and still more distinctly Archibald Geikie, had recognized that, in the so-called plains of marine denudation, the greater part of the work of erosion is really effected by subaerial agencies. But it required the study of our western plateaus to develop the doctrine of base-levels into the form which it has taken in the writings of Powell and Gilbert.

To the last quarter-century belongs the development of modern Lithology, or Petrography. It was in 1862 that Sorby called the attention of Zirkel to some microscopic slides which he had prepared, and thenceforward Zirkel devoted his life to the systematic development of the new mode of investigation. The year 1867 was the date of the first general work in which the subject of Lithology was treated from the new standpoint—the "Philosophie der Geologie" of the lamented Vogelsang. While the modern Lithology is characterized especially by the application of the polarizing microscope to the examination of thin sections, microscopic work has been supplemented by new methods of analysis, such as the use of solutions of high specific gravity for the separation of the various ingredients of rocks, and the application of powerful electro-magnets for the isolation of iron-bearing minerals.

Too much time for your patience, though too little for the adequate treatment of the subject, has been given to the history of the two sciences especially cultivated by our Association, Biology and Geology. Only a passing glance can be given to the progress of other sciences.

In 1867, there was no refracting telescope in any astronomical observatory with an object-glass of more than eighteen inches diameter. That size has been doubled in the objective of the telescope of the Lick Observatory. In 1867, Spectroscopic Astronomy was yet in its infancy. Its revelations of the physical constitution of the heavenly bodies, and their motions relative to the earth, its discovery of double stars too remote for any telescope to resolve, were yet in the future. The investigations of Newton and Schiaparelli on the relation of comets and meteors were published about the beginning of the period which we have under review.

Twenty-five years ago the doctrine of the Conservation of Energy was still a new idea struggling for acceptance, although Joule's determination of the mechanical equivalent of heat had been made as early as 1850. Carpenter had already announced the correlation of physical and vital forces; but that phase of the general doctrine was still counted heterodox.

Ferrel had given the key to the true theory of the winds as early as 1856; but twenty-five years ago his work was generally ignored. His views have in fact found their way into the text-books on Meteorology and Physical Geography only within the last few years.

During the last quarter-century there has been an immense expansion of the quantitative, in distinction from the merely qualitative, study of electrical phenomena, and a vast development of the practical applications of electricity. The earliest successful trans-oceanic telegraph cable was laid in 1866—only one year before the date at which our survey of scientific progress begins. Essentially, therefore, to this quarter-century belongs the development of submarine telegraphy, as well as the invention of the telephone, and the practical development of electric lights and electric motors.

Twenty-five years ago we were accustomed to speak of certain substances as "permanent gases," in distinction from carbon dioxide and certain other substances, gaseous under ordinary conditions, but capable of liquefaction under the action of cold and pressure. The phrase and the idea have been abolished by the brilliant experiments of Pictet and Cailletet.

Twenty-five years ago Avogadro's generalizations in regard to the molecular constitution of gases were just in process of resurrection, and the new chemical formulas were gradually displacing the old ones. At that time Organic Chemistry still wore an aspect of something like magic or supernaturalism, and had not yet become simply the chemistry of the compounds of carbon. Wöhler, indeed, had produced urea by artificial synthesis in 1828, and Kolbe had produced acetic acid in 1845; but in 1867 the list of organic compounds which had been artificially produced was still exceedingly short. And none would have ventured to prophesy the great progress which the past quarter-century has achieved. Few enthusiasts would even have dreamed of what has been accomplished in Schützenberger's recent synthesis of something which, if not actually a peptone, is at least very like one.

Incidentally, Chemistry has furnished very great assistance to a number of the sciences, and especially to Astronomy, by the introduction of improved methods of photography. The extremely sensitive dry plates which have been introduced, have rendered it possible to preserve photographic records of many kinds of phenomena, in presence of which the photographer of twenty-five years ago would have been utterly helpless.

In 1867, there were four burning questions under consideration—evolution, spontaneous generation, the antiquity of man, and the correlation of physical and vital forces. They burned with an ardor which was by no means purely scientific. There was an *odium theologicum*, and an *odium atheologicum*. The belief was widely diffused, among both progressive and conservative thinkers in science, and among both orthodox and heterodox thinkers in theology, that the religious beliefs of the future would depend upon the solution of these doubtful scientific questions. If the opinion should prevail that the various species of living beings, and especially if the opinion should prevail that the earliest living beings, had originated otherwise than by special creation, men would cease to believe in a God. If the date of the introduction of man upon the planet should be proved to be more than about six thousand years ago, men would lose all faith in supernatural revelation. If the correlation between physical and vital forces should be established, men would lose their faith in the spiritual nature of man, in moral accountability, and in immortality. Any one of these questions might prove, in the old theological language, *articulis stantis vel cadentis ecclesiæ.* Widely diffused as were these expectations,—taking the form, in various minds, of hopes and fears,—there were some who recognized twenty-five years ago that the main outlines of religious belief were independent of any answer which might be given to those purely scientific questions. The profoundly philosophic mind of Asa Gray saw clearly, in the very beginning of the Darwinian controversy, that there was no incompatibility between the doctrine of Evolution and theistic or Christian belief; and stated his views in an essay entitled, "Natural Selection not inconsistent with Natural Theology," which still remains unsurpassed as an exposition of the theistic philosophy of Evolution.

The writer of the thesis on the Darwinian theory, to which allusion was made in the introduction of this address, may at least congratulate himself that, though not wise enough to recognize in 1867, as he recognized a few years later, the probable truth of Evolution, he protested even then against importing theological considerations into a purely scientific discussion, and maintained the consistency of Evolution with theistic philosophy and Christian faith.

The younger generation of scientific students can hardly appreciate to-day the agonies of terror with which the doctrine of Evolution was regarded by many religious men twenty-five years ago, and the intense bitterness with which the theory and its advocates were denounced. An irenic era has supervened upon the period of conflict. Now and then, indeed, some theological Rip van Winkle attempts the old Sinaitic thunders in denunciation of the essential atheism of Evolution; but his utterances are regarded by his brethren in the church, not with sympathy, but with amusement or mortification. The curriculum of an orthodox theological seminary is hardly regarded as complete to-day without a course of lectures on the consistency of Evolution with theistic philosophy. Spontaneous generation, as supposed to be proved by the experiments of Pouchet, Child, Bastian, Wyman, and others, is, indeed, universally rejected; but, on the strength of general analogies, the scientific world of today is practically unanimous in the belief that life must have originated by some sort of natural process: and the announcement no longer shocks the religious feelings of any intelligent person. A belief in an antiquity of man far exceeding the six thousand years of tradition is regarded by the theologians of to-day with acquiescence or approval. Even the conservative professor of Hebrew in Princeton College declares that the Bible does not fix the date of man's origin. The correlation of physical and vital forces is practically everywhere admitted, and the faith in moral accountability and in immortality is as widely diffused and as vigorous as it was before. In the changing environment, Christianity has not become extinct; but has varied slightly, and become adapted. It has seemed to show that power of adaptation to new environment which entitles an organism to be preserved by natural selection.

The student of the history of human thought recognizes that the story of this conflict and its peaceful end is but a repetition of the past. The Copernican Astronomy was even more revolutionary, in its bearing upon traditional theological beliefs, than the Darwinian Biology. But then, as now, adaptation, and not extinction, was the fate of Christianity.

We make no prophecies. As scientific men, we know too well the fallibility of all processes and the uncertainty of all results of human thought, to suppose ourselves to be the custodians of absolute truth on any subject. Our creed-revisions come not once in three hundred years, but every day. We hold no belief to-day on any subject which we are not ready to abandon to-morrow. But the histories of past conflicts suggest that Christianity survives because it meets the moral needs of mankind—because, whatever errors or superstitions may have been linked with it, and supposed by its foes or its friends to be an integral part of it, it contains essential truth.

It well may be that, as long as man the finite seeks to gain inspiration from the infinite, as long as man the sinful seeks moral uplifting by the contemplation of the not-himself "that makes for righteousness," so long will there be need of anthropomorphic symbols for the mysterious Power "dwelling in the light which no man can approach unto, whom no man hath seen, nor can see;" and so long the truest symbols to represent a truth which, in its real essence, transcends all human expression and all human thought, may be those afforded by him who taught the world to say, "Our Father who art in heaven."