ARTICLE II.

THE ADAPTATIONS OF NATURE TO THE INTELLECTUAL WANTS OF MAN.

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THAT man should be able to interpret nature, and from the experiences of the present both reproduce the past and forecast the future, is a mystery of the first degree. It was considered a marvellous triumph of human ingenuity when Champollion deciphered the hieroglyphics of Egypt, and opened to his followers the vast stores of information which had been so long concealed in them. But his success was due to the fortunate discovery of a key in the celebrated Rosetta stone, which contained an inscription in Greek translating the parallel inscription in hieroglyphics. Sir Henry Rawlinson's success in interpreting the cuneiform inscriptions was due to a similar fortunate experience. In these cases the interpreters were dealing with the works of men whose capacities were altogether like their own. Man cannot, if he would, wholly deceive his fellow-men. In knowing the restrictions of our own powers we know those of our fellow-men. Hence it comes about that cipher despatches, designed to deceive all but those specially initiated, can never wholly baffle the skill of experts. Some clue exists, and, when discovered, readily yields the secret.

To the thoughtful student of nature, there is no other evidence of the goodness of the Creator so impressive as the fact that his works are capable of interpretation by the mind of man. That the infinite mind should make his thoughts known to the finite, betokens a condescension which only a benevolent being would exercise. It is as when the full-grown man shortens his steps in the drifting snows, in order that the child behind him may have a beaten path through which to reach the safety of his home. Or, as when a great philosopher like Faraday condescends to speak for the instruction of children, and puts his profound thoughts in language so simple that the infant can understand. The more fully we realize the fact that the Creator is infinite in power, that his thoughts are above our thoughts, and his ways above our ways, the more wonderful does it seem that the works of God can be understood by us at all. Yet, as a matter of fact, we do find nature comprehensible, and capable of interpretation. We are able with confidence to reconstruct in thought a large portion of the past, and to forecast in hope the distant future. The Creator has so graduated his steps in nature, that man can follow them in the past, and calculate their course in the future.

In maintaining this point it is not necessary for us to contend that we can fully understand the works of God, for this is not needful for our present well-being. Indeed, there could be no greater calamity than for man to have attained to all knowledge. No small part of the joy of finite existence consists in the progressiveness of its condition. The gratification of curiosity, the joy of animated search for truth, and the satisfaction of discovery are things with which, as finite beings, we could not well dispense. It is, in fact, a real question, whether, in the majority of cases, the privilege of searching for the truth is not more valuable than the truth itself when once attained.

The mystery of inductive reasoning can be solved only by regarding the adaptation of nature to the intellectual capacity of man as a product of benevolent design. Indeed, it is not strange that some, like the Abbé Gratry, should believe every true induction to be "an immediate inspiration from on high";[1] nor that others like Hume should declare, that "reason can never satisfy us that the existence of any one object does ever imply that of another; so that when we pass from the impression of one to the idea or belief of another, we are not determined by reason, but by custom, or a principle of association."[2] The falsity of this proposition of Hume, however, becomes apparent in noting the progress of modern science. Science has flourished not where custom reigned supreme, as in China, but where the mind of the investigator is prepared to discard all inveterate associations, and to accept the reality of things which run contrary to all the reputed experience of the past.

In searching for the philosophical basis of modern progress and scientific discovery, much use has been made of the misleading phrase "uniformity of nature." It has frequently been said that we expect the future to be as the past because we believe nature to be uniform in her operations. Confidence in this principle, however, disappears upon close inspection, since there is nowhere any absolute uniformity in the operation of nature. There is a *course* of nature; and there is, no doubt, a causal connection between the events which come before and those which follow after. But this ongoing of nature is an evolution, rather than a uniformity; and the evolution is not constant, and by steps of equal length, but is rhythmical and to some extent paroxysmal.[3] As Mill truly says, "Every person's consciousness assures him that he does not always expect uniformity in the course of events; he does not always believe that the unknown will be similar to the known, that the future will resemble the past. Nobody believes that the succession of rain and fine weather will be the

[1] Popular Science Monthly, Vol. xii. p. 117.

[2] On the Understanding, sect. vii. (Works, vol. i. p. 128. Boston and Edinburgh, 1854.)

[3] See my Studies in Science and Religion, pp. 8–11; Logic of Christian Evidences, p. 96.

same in every future year as in the present. Nobody expects to have the same dreams repeated every night. On the contrary, everybody mentions it as something extraordinary, if the course of nature is constant, and resembles itself, in these particulars. To look for constancy where constancy is not to be expected, as, for instance, that a day which has once brought good fortune will always be a fortunate day, is justly accounted superstition."

All nature is in motion. Everything changes. Nature never exactly repeats herself. The sum of the forces in the universe may, for all we know, remain uniform, but their interactions upon each other are infinitely diversified. In its search for absolute uniformity, the reason pauses only when it reaches the wisdom and benevolence of the Creator. It is the prerogative of science to penetrate deeper and deeper into the course of nature, until, under the magnifying power of Reason's eye, the so-called uniformities of nature disappear in the dissolving view spread upon the canvas of the infinite. Nature's operations seem uniform to us, because our minds are so slow in their ordinary actions. When we drop the element of time from our thoughts, and consider nature in its causes and effects, or compare movements separated by vast intervals of time, the ordinary conception of uniformity vanishes. Fifty millions of years ago the sun did not rise at intervals of twenty-four hours, and the moon did not go through her phases once in twenty-seven days. The mathematicians[1] tell us that, through the retarding influence of the tides, the rate of the revolution of the earth has diminished from that of a period of three or four hours, fifty million or a hundred million years ago, to one of twenty-four hours at the present time. The same authorities tell us that, at the early date spoken of, the moon almost touched the earth, and revolved

[1] Geo. H. Darwin, Nature, Vols. xviii. pp. 265, 580; xix. p. 292; xx. p. 246; xxi. p. 234; xxiii. p. 389; New Princeton Review, Vol. lxi. p. 59; Popular Science Monthly, Vol. xxix. p. 449.

about it in the same time that the earth itself rotated upon its axis.

In inductive reasoning, progress is made, and truth attained, by discovering the material embodiment of the Creator's ideas; so that we do truly think his thoughts after him. The creation is a realization of divine ideas prepared for our study. With our limited vision we can discover the plan and development of so much of the whole as our necessities demand. The repetition of given phenonema in nature reveals to us second causes in their isolated action. The variations in the phenomena reveal to us second causes in their combined action. By careful observation and comparison, indeed, in chemistry and astronomy, and by the use of mechanical instruments of precision and of the formulæ of mathematics, this process of observation and comparison is greatly aided. These reveal to us more fully the rate of change in progress, and the relative importance of the several causes involved.

Complete analysis will show, however, that rational confidence in our interpretation of nature rests upon the ethical judgment that God is wise and good, and that his veracity is involved in the orderly arrangement appearing in nature. The law of benevolence demands a correlation between the powers of human apprehension and the rate of change which is taking place in the evolving system of secondary causes which we call the universe. The repetition of like events, to a certain extent involves God's veracity. Our part is to inspect the course of nature, to learn the degree in which the present is like the past, and from that experience, first, to infer the degree of likeness which, on the theory of their being the work of a wise and benevolent Creator, ought to exist in periods earlier than our experience in time, or beyond its reach in space; secondly, to prognosticate the future. This is the meaning of those vague expressions, "The present is conformable to the past"; "The future will resemble the present"; "The future will be like the present," etc., which we find in writers on the philosophy of induction.

We can best impress this thought upon our minds by taking a brief survey of the accomplishments of modern science. And in such a survey, better than by any other method, we shall come to realize what an immeasurable chasm separates man from the lower animals,—a superiority which can be maintained without any depreciation of their capacity.

The animal creation, indeed, is endowed with instincts in many respects far superior to those of man. But, instinct and reason would seem to vary in inverse ratio: the more complete the instinct, the less the need of dependence upon reason. The power of instinct, for example, is strikingly seen in the annual migrations of birds. Yet how simple and insignificant are these movements when compared with the commerce of nations; for, while the power of the bird to direct his migrations seems to belong to the very physical development of the bird, the skill of the captain and pilot is the cumulative wisdom of many centuries, and the accomplishment of their purposes is secured by a combination of skilled workmen and successful inventors from every age and clime. The pilot guides his course by the stars and depends upon the painstaking calculations of the mathematicians who make up the nautical almanac. The inventor of logarithms renders indispensable assistance to every ship which sails the seas. Think, too, of the skill which enters into the construction of a ship, of the genius which, within the past few years, has transformed the whole art of shipbuilding,—making iron to swim, and substituting the ore dug from the mountains for the timber cut from Norwegian hills. Think also of the inventions which, by the introduction of steam, have made the pilot independent of the winds. Indeed, it would require a volume simply to enumerate and describe the scientific inventions of which every one of the great ocean steamers makes use during every hour of its long voyages.

In entering upon a narrower survey of the subject, we note how the science of chemistry illustrates both the power of the human mind to interpret nature, and the admirable manner in which nature's steps are graded to the wants of the inquiring mind. By such slow and toilsome steps as are best for the moral development of the race, the marvellous results of this science have been attained. Here, as elsewhere, a high premium has been set on that humility of mind which is the first condition of entering the kingdom of heaven.

Illustrations from Chemistry.

The modern science of chemistry really dates from the discovery of oxygen by Priestley, in 1774, though this great investigator failed himself to appreciate the meaning of his discovery, and was, a quarter of a century later, still an opponent of the new views of chemistry brought to light by his own ingenious experiments. For fifty years previous to this, the phenomena of combustion had been explained upon Stahl's modification of Aristotle's theory (1660–1734), that all combustible bodies contained phlogiston, which was expelled during the process of combustion, leaving the other constituents of the substance behind.

We smile now at this conception; but what can be more natural, on the face of the phenomenon, than such a theory of combustion? For when a fire blazes, does not something seem to go out of the substance which is burned? The source of the error here, as frequently, lies in the fact that the outward appearance is deceitful, and that nature unfolds her secrets only to the diligent student who goes behind the appearance, and pays respect to the deeper currents of cause which underlie all her great operations. Thus, upon this theory, when phosphorus was dephlogisticated, or burned, the resulting phosphoric acid was a residue—phlogiston had gone out, and phosphoric acid was left. That certainly is what seems to have occurred. Again, when the metals were dephlogisticated, or burned, a calx was left. But, on the other hand, when limestone was burned, it appeared to have absorbed phlogiston, for it had a great deal of heat to give out when water was poured upon it.

A puzzling thing on this theory, however, was, that when limestone was burned, and so according to the theory became charged with phlogiston, it weighed less than before it was burned. This phenomenon seems to have escaped the attention of the theorists of the eighteenth century, until Black, of Edinburgh (1728–1799), discovered the fact in 1755. But the theorists were ready with an explanation. They said that this proved that phlogiston had the power of levitation. This explanation was the more readily accepted, because Aristotle in his time had familiarized the world of letters with the idea that the essence of fire was specifically light. Now, what Black had really discovered was, that the thing expelled from limestone when it was burned was carbonic dioxide, which he called fixed air. When it came to be understood, the difference between the weight of limestone just before it was burned and that just after, measured the amount of carbonic acid gas which has been expelled. But mere instinct and plodding observation never could have given this interpretation. The interpretation was really a marvellous stroke of genius, or what Abbé Gratry would call an inspiration. We may therefore well pause a little longer upon this line of discovery.

Cavendish (1731–1810) in 1765 investigated hydrogen, and was led to believe that he had discovered phlogiston at last. Its great lightness attracted his attention, and he named it inflammable air. In 1784, however, he discovered that, if hydrogen be used in the phlogistication of common air, common air was diminished in volume, and water was produced; while Priestley, in 1774, had discovered the companion of Cavendish's phlogiston in oxygen gas, which he denominated dephlogisticated air.

During the very next year Lavoisier discovered that when the oxide of mercury was heated with charcoal, it produced not dephlogisticated air and metallic mercury, but metallic mercury and carbonic acid gas, or what he called fixed air. By continued experiments Lavoisier made other discoveries in the same direction. A more accurate weighing of the elements showed that, in what is called the calcination, or the burning, of metals in air, the metal gains as much weight as the air loses.[1] He also discovered that combustion of fuel, the respiration of animals, the formation of acids, and the calcination of metals were analogous in this respect, that they withdrew from the air a common element, which he named vital air, but which we now call oxygen. In short, Lavoisier had discovered that, where the old theory held that phlogiston was substracted from a substance, the very opposite had really occurred, and "vital air," or the acid principle, was added. In short, combustion was an oxidation, instead of a dephlogistication.

But old theories have great vitality, and this theory of dephlogistication did not die easily. Some objections seemed for a time insurmountable. For example, when metals were dissolved in weak acids, it was found that what was then called inflammable air, or hydrogen gas, was produced. But the previous discovery of Cavendish, already referred to, that hydrogen and oxygen when burned together produced water, furnished Lavoisier the clue to the difficulty. He surmised that, when metal was dissolved in acid, and hydrogen was produced, some of the water was decomposed. This he also verified by burning oxygen and hydrogen together, thus making a little water, and then separating the water again into its elements by passing it over red hot iron; whereupon the oxygen united with the iron, and the hydrogen was set free. Lavoisier afterwards "showed the consistency of his theory with all that was discovered concerning the composition of alcohol, oil, animal and vegetable substances, and many

[1] Whewell, History of the Inductive Sciences, Vol. ii. p. 274.

other bodies." And so, within twenty-five years from the discovery of oxygen by Priestley, the theory that combustion and analogous phenomena were produced by the combination of elements, rather than by their separation, was generally accepted, and the quantitative method of investigation, which has since characterized the science of chemistry, came into use, and from it have followed all those marvellous results of chemical science upon which it almost may be said that the human race now lives, and moves, and has its being.

How sublime are these triumphs of genius when compared with any of the results attained by instinct! What an illustration, also, is here presented of the pains the Creator has taken to secure adaptation between the faculties of man and the intelligible marks of causation running through the system of nature! How closely connected have been the links of this chain of progress! Had any of these links been too long for man to span, progress would have been impossible. There is no way of avoiding here the argument of design. Either nature was designed for man, or man was designed for nature: and it makes no difference, so far as the argument is concerned, which was designed first. The supposition that any intelligent being should arise or be developed, to make this use of nature, by accident, is incredible. The *power* of God is seen in creating such an adaptation, and at the same time the *wisdom* and *goodness* of God are seen in setting an appropriate premium upon the diligent use of man's faculties and opportunities. *It is only those who seek who find.* The consciousness of power that comes to the whole race by such achievements is of incalculable value.

But we have still more marvellous achievements to relate in chemical science. What at first sight would seem more unlikely than that the chemical composition of the sun should be revealed in the rainbow! And yet the story is all there awaiting interpretation, and we have now learned to study known metals by analyzing the rays of light which stream from them in the act of combustion, and by the same means to detect the presence of unknown metals. For example, in 1860 the first indications of the metals cæsium and rubidium were detected by Bunsen and Kirschhoff, from the use of the spectroscope, then just invented. Certain mineral waters had been evaporated, and the residuum was burned by these chemists under intense heat. The flame showed some lines of light never before observed, and led them to suspect the existence of new mineral elements. But so small an ingredient were these minerals in the water of the Dürkheim Springs, that forty-four tons of it had to be boiled away to obtain sufficient residuum for ordinary analysis.[1]

Chemistry is what is called the typical experimental science. But, clearly, it is far more than an experimental science. The results are obtained not so much by experiment, as by thought. A dull, aimless repetition of experiments might continue forever without producing any valuable results. The great chemists are great men, and Providence has provided for them a great opportunity. Had not the men been matched by the opportunities, their striving would have been in vain; and, had not the opportunities been matched by the men, the results would have been insignificant and misleading.

Illustrations from Astronomy.

The science of astronomy illustrates the theme, also, in a high degree. Few appreciate the original difficulties in the way of establishing the astronomical theory which now prevails among scientific men, and upon which are built so many practical plans and inspiring theoretical conceptions of the present time. There is little direct resemblance between the falling of an apple and the revolution of a planet about its central sun. The intellect that first thought of the analogy must have been of heavenly birth; while the marvellous skill by which the theory of universal gravitation has been verified,

[1] Eclectic Magazine, June, 1870, pp. 652, 653.

would have been of no avail, except for a special adaptation of the solar system to reveal the theory. After Newton's hypothesis had been propounded, it remained yet to be verified by showing that such a cause as gravitation would produce the actual motion of the heavenly bodies. This involved the celebrated problem of the interaction of three moving bodies upon one another. But to tell with absolute exactness how the sun, the earth, and the moon would affect each other when their rates of motion and their relative positions to each other were undergoing constant change, surpasses the power even of modern mathematics.

As Whewell has remarked, "The result must be got at by successive approximations. We must first find a quantity near the truth; and then by the help of this, one nearer still, and so on; and in this manner the moon's place will be given by a converging series of terms. The form of these terms depends upon the relations of position between the sun and the moon, their apogee, the moon's nodes, and other quantities; and by the variety of combinations of which these admit the terms become very numerous and complex. The magnitude of the terms depends also upon various circumstances; as the relative force of the sun and earth, the relative times of the solar and lunar revolutions, the eccentricities and inclinations of the two orbits. . . . Even the possibility of doing what has been done depends upon what we may call accidental circumstances; the smallness of the inclinations and eccentricities of the system, and the like."

So that Legrange used to say, "If nature had not favored us in this way there would have been an end of the geometers in this problem."

The close connection between all sciences and the essential unity of human thought is admirably illustrated in some of the modern processes of astronomy. There would seem at first sight to be little connection between chemistry and astronomy, and yet it may be truly said, that astronomy is now a chemical science, chemistry having almost wholly revolutionized the modes of astronomical investigation. It was the chemists who invented photography, and now the camera, rather than the great telescope, is the chief means of astronomical research. Toward the close of the last century, Captain Cook was sent with an astronomical party to the Pacific Ocean to observe the transit of Venus. The event was carefully watched, and every observation noted down. But the human eye is not perfect, and no two persons ever see things exactly alike. Hence there were discrepancies in the observations which could be eliminated only on general principles, as there was no record of the event except the recorded impressions of the witnesses at the time. But the recent transit of Venus was observed by the unerring action of the photographer's sensitive plate, which gives an abiding record. By this marvellous chemical art, stars which no eye has ever seen can be readily photographed. But this, again, is dependent upon the skill of the clockmaker, who can so adjust the motion of his pendulum that it shall give such a movement to a photographic plate that, notwithstanding the motion of the earth, a particular point of the heavens shall, for a considerable period, be kept in focus upon it. Thus by accumulating the chemic forces of rays of light which is too feeble to be recognized by the retina of the human eye, a permanent impression can be made, and a perfect map constructed, of stars of all magnitudes occupying a limited space in the sky. The great astronomical observatories of the world are now engaged in a combined effort thus to photograph the whole heavens, and so have a permanent record to be compared with similar maps which shall be made in future times.

How different is all this from the action of instinct, and how marvellous the power bestowed upon the human mind by which it can rise above the natural limitations of the physical organization through which it works, and make use of these occult laws of nature, and through them see with the mind's eye relations that are not even faintly suggested on the face of nature!

Illustrations from Geology.

The same truth is illustrated in the science of geology, which treats of the material history of the earth. We have not space to unfold in order all, or even many, of the leaves of this most interesting volume. We will therefore limit ourselves to illustrations drawn from a single page of the geological record.

The signs of the glacial period, for example, are pre-eminently adjusted to the capacity of the human understanding. The glacial theory is not a thing to be apprehended by instinct, but only by the slower and surer processes of inductive reasoning. A dog can scent his living master through a crowded thoroughfare, but how absurd to expect him to trace the footsteps of a prehistoric man through the mazes of his glacial history!

The characters in which the story of the ice age are told are essentially like those of a cipher despatch: they are unintelligible when seen singly and without a clue, and are only comprehensible to a reasoning mind of high capacity. The information which, however, they reveal, when once the clue is found and the facts are brought together, is astonishing both in character and in amount, and the story of the ice age is every whit as interesting and as full of surprises as the tale of the Arabian Nights. What, for instance, at first thought would be more unlikely than that the mud banks of some obscure stream in the northern part of the United States should yield information concerning the age of man in Upper Egypt! and yet such is the solidarity of science, and so bound together in a system are the connected marks of causation in the universe, that this possibility is by no means remote.

Through long-continued comparison and study of the ruder forms of human implements, it has come to be the well-established opinion of archæologists that there was a great similarity in the character and form of the stone implements earliest in use among the various tribes of the human family. This earliest type of implements is unpolished and rude in shape, being made out of flint or argillite or quartz, substances which are capable of being worked to an edge by a rough process of chipping. With these rough stone implements, or palæoliths as they are called, early man performed all his work. His arms of offence and defence, the weapons with which he attacked the gigantic animals associated with him, and the implements with which he tilled the soil, or felled the forest, and hollowed out his canoes, were all made from stone by this process of fracture, and without any attempt at polishing.

Implements of this sort are so widely scattered, and so exclusively connected with a certain class of gravel deposits, that the inference is legitimate that they as universally preceded the use of smoothed stone implements as the use of polished stone preceded that of bronze, and bronze that of iron. The type of palæolithic implements is also strikingly uniform. Photographs of those from Northern France are so strikingly like those from Upper Egypt, and from Trenton, N. J., that one might plausibly infer that the Garden of Eden was in the vicinity of Paris, and that from the very earliest times, as now, the fashions radiated from that centre.

Attention was not specially directed to this class of implements until twenty-five or thirty years ago, when it was ascertained by Boucher de Perthes, and his coadjutors in the study of the gravel deposits in the valley of the Somme in France, that palæolithic implements occurred in the gravel terraces along that stream in such position as to indicate a much earlier age than had heretofore been assigned to man.

The implements were found in gravel banks, on the side of the valley, about one hundred feet above the present flood-plain, indicating that the river, though now but a small stream, had lowered its whole trough, which is about a mile wide, to that extent since the gravel was deposited in which these implements are inclosed. The distinction between the races using these implements and those using smoothed stone implements was made manifest by the fact that only implements of the rougher sorts are found in these ancient gravels, and, still further, by the fact that various gigantic animals which became extinct before the historic period are found associated with the deposits containing palæolithic implements, but not with the implements of the other class. The examination being extended to other portions of the country, a similar class of facts was found to occur in Southeastern and Southern England, and in addition the deposits in various caves which had been occupied by man yielded similar results; the lower strata contained palæolithic implements and the bones of extinct animals, while the upper strata conformed more and more nearly to the conditions of the historic period.

When once this principle of the priority of the rough stone implements as a type was established in Europe, it became of interest to archæologists to know whether the same priority existed in other parts of the world. The establishment of the fact in this country is due to the labors of Dr. C. C. Abbott, of Trenton, N. J., who early became a collector of the ordinary Indian implements abounding in his favored locality. In 1875 Dr. Abbott was fortunate enough to discover some implements of a palæolithic type deeply imbedded in the deposit of gravel upon which the city of Trenton is built. From time to time similar discoveries, to the number of thirty or forty, have been made by him in the same gravel deposit. The instructive fact is that here, as in Europe, only implements of this type have been found in such gravel deposits as that at Trenton.

About the same time that Dr. Abbott was finding his implements in Trenton, N. J., Professor Henry W. Haynes, of Boston, devoted himself to studying the archæology of the

Nile in Upper Egypt. He likewise was fortunate enough to find in the gravel of the Nile and Upper Egypt palæolithic implements of the same type as those in the valley of the Somme and of the Delaware. These cannot be so definitely connected with the glacial period as can those of which we have been speaking in France and America, but it is probably for the reason that the glacial period was limited to more northern latitudes. Still, the similarity of type, and its disappearance in giving place to other types of implements in all three of these regions, is significant, while in France and America the occurrence of the implements in undisturbed beds of gravel at once transfers the question of antiquity from the realm of archæology proper to that of geology.

The gravel containing this class of implements can be connected with the closing portion of the glacial period in America. The terrace upon which the city of Trenton, N. J., is built is such as is characteristic of all the southward flowing streams in and on the border of the glaciated region. Nor is the evidence of this connection wholly confined to the locality of Trenton. But, since Dr. Abbott's discoveries, other similar discoveries in gravel similarly deposited have been made of implements in the valley of the Little Miami, in Southern Ohio, of the White River, Indiana, and of the Mississippi in Minnesota. The age of these implements, therefore, becomes a question of glacial geology. The archæologist must now ask, How long ago was the glacial period? When did it close? At what stage of the period were these gravel deposits formed?

The connection of sciences was here again illustrated in the fact that the most popular attempt to solve the problems of glacial chronology and antiquity uses astronomical methods. Mr. Croll propounded a theory that the glacial period was caused by certain astronomical changes whose influence could be definitely pointed out. Through the influence of the precession of the equinoxes and of changes in the eccentricity in the earth's orbit, it was contended by Mr. Croll, conditions of climate favorable to the glaciation of the northern hemisphere occur once in about 21,000 years; that one of those periods occurred about 11,000 years ago, but that the maximum effect of the conditions, such as could be supposed to produce a glacial period like that which covered the northern part of the United States so deep with ice, could have culminated not less than 180,000 years ago, near the close of a period of high eccentricity in the earth's orbit.

This was an easy and attractive method of settling the questions of glacial chronology. And, if it had been merely a question of astronomy, since these changes in eccentricity are definitely known to have taken place, the question would have been settled beyond controversy. But, unfortunately, astronomy, like mathematics, consists of two divisions, namely, pure and mixed. In estimating the effect of physical forces we must be sure to know what the forces are, before we apply our multipliers, and divisors, and all the instruments of the calculus to them. It is so with this attractive theory as to the date of the glacial period. We cannot be sure that the acknowledged astronomical changes would produce the climatic changes which the mathematicians suppose. Here, also, it is impossible with present limits to go into details. But it is sufficient to say that the meteorologists and the geologists who are studying the subject, from their knowledge of the connected facts, have become quite generally convinced that the astronomical theory is not sufficient to account for the facts, or, at any rate, that it is not proven to be sufficient. In whichever case, the question of calculating the date of the glacial age is remanded to those who are engaged in the study of the glacial phenomena as they exist all over the country.

What now are the direct means by which the geologist can approach the subject? At first it would seem like a hopeless task. But close inspection shows that here, as elsewhere in nature, the Creator has not left himself without witness to those who closely scan his ways. Geology, as well as astronomy, has its chronometers. Those of the glacial period are to be found in the deltas, the river valleys, and the waterfalls of the glaciated area.

Three of the most significent questions which thrust themselves upon the student of glacial geology are these: 1. Why are there so many lakes in the glaciated region? 2. Why are the troughs of the rivers so small in the glaciated region? 3. Why are there so many waterfalls in the glaciated region?—questions which it is inconceivable that any animal should ask.

But even in the time of Solomon the question was asked, Why is it that when all the rivers run into the sea, the sea is never full? This we can now answer. We say it is because the evaporation equals the precipitation. The other more recent questions we can also now answer with great confidence.

1. The lake basins are not filled with sediment, because their life has been short. The rivers have not been engaged in this work forever. For, evidently, it is only a question of time when, through the erosive agency of the rivers and their innumerable tributaries, the valleys shall all literally be exalted and the hills made low. In every lake basin, therefore, of the glaciated region, (and there are scarcely any lakes anywhere else) the thoughtful inquirer has a problem inviting him to the exercise of his ingenuity in answering one of the most interesting of all historical and archæological problems, namely, the antiquity of the human race. In innumerable cases these little glacial lakes, which so beautify the landscape, present a very well-defined problem, since they are so small that their original as well as their present depth can be estimated, and the amount of sediment carried into them already can thus be approximately determined. The observer, therefore, has only to calculate the size of the drain-

age basin, and the amount of the sediment in the streams, and the problem is solved. Not all of these elements can be easily obtained. But most are attainable, and the problem invites effort at solution and presents a reasonable hope of success. The problem but awaits the response of the inquiring mind.

2. The problem of the river valleys is similar. Why have they not enlarged themselves more than they have in the glaciated regions? The answer, in the majority of cases, clearly is, Because they have not had time enough. Give these rivers time, and they will remove every particle of the *débris* with which the ice of the glacial period has clogged them. They are busily engaged at this work all the while, and are producing results which can be observed and measured. Here again nature is awaiting the intelligent questioning of the inquiring mind. Long before the time of our Saviour, even from the very beginning of human history, the divine word had gone forth, that to him that knocketh it shall be opened, and only to him. A fair premium is set upon a diligent use of our powers, but the reward is ever near. It is thus that anyone is warranted in putting inquiries concerning the age of man in Delaware, and France, and Egypt, to any sluggish stream in the glaciated region.

3. The third question, Why are there so many waterfalls in the glaciated region? leads to the same goal. The great majority of the waterfalls of the world are in the glaciated region, and they exist because the time is so short since the ice withdrew and suffered the water to run in its present channels. It has recently been ascertained that the Falls of Niagara are receding at the rate of from four to five feet per year. This is the result of accurate observations carried on during the past forty-five years. It was also ascertained long ago that the Falls of Niagara did not exist before the glacial period. The gorge below the falls is therefore another glacial chronometer. This gorge is only about seven and a

half miles long. The date of the close of the glacial period therefore resolves itself into a simple sum in division, namely, How many times will five feet go into seven miles and a half? If there had been indefinite time since the glacial period, the falls would have receded to the bed of Lake Erie long ago. But, as it is, the work done indicates for the cataract a life of only a few thousand years.

This is but one of innumerable instances in which, by studying the recession of waterfalls, some clue can be obtained respecting glacial chronology, and so, by inference, of human chronology.

But let us pause a little, at this point, to reflect upon the significance of such facts as have been already presented in their bearing upon the theme of our discussion. No one can have gone thus far in this enumeration without being impressed with the intelligibility of nature, and with the marvellous additions to human knowledge coming from what seem at first most unlikely sources. Nor can he help being impressed with the grandeur which this power of research and discovery gives to man. This life is ennobled beyond measure both by the power of research bestowed upon the human race, and by the preparation of a field so enticing to the inquirer and so richly rewarding his inquiries. One has only to take up any physical geography of the present time to see, at a glance, how much there is in it both to enrich the life of the child who studies it, and to prepare him for partnership in the joy of all future discoveries recorded by the daily press. What sublimity there is to a thoughtful mind in the daily reports of the weather bureau, which records the progress and the contest of the various storm-centres the whole world over! The isobars upon the maps of the physical geographies, which surround the areas of equal barometric pressure, become invested with symbolic meaning and through them the reader sees with the mind's eye the movements on the grandest scale of the mightiest of physical forces. The record reads: Low pressure of the barometer on the Atlantic coast; high pressure in the Northwest. To the mind's eye this means a gradient as real as that down which a river flows, or the cars on an inclined railroad run with accelerating speed. Thus viewed, how abundant are the provisions here made for man's intellectual enjoyment, as well as for his physical well-being!

The world is full of similar enticements to intellectual effort. There is no spot so barren but it bristles with interrogation points. And there is a science adapted to every kind of mind. If not interested in one line of investigation, the student finds countless others suited to his taste. Recurring to the glacial period, one says he is not interested in archæology and the antiquity of man, and he cares nothing about glacial dams, glacial mill-ponds, and all that ilk. But perhaps he cares for botany, and admires the tiny flower that nestles in the wall, and the luxurious vine that covers the decaying oak with its mass of verdure, or the stately cedar that mantles Lebanon with its solemn shadows. Yet in studying the distribution of these over the earth, one will find himself unwittingly paying deference to glacial geology. For what but the great ice-sheet was it that drove down from the far north, to their present habitat, the Bald Cypress of the Southern States, the gigantic Sequoias of the Pacific coast, and their near relative the Chinese Glyptostrobus to the mountains of Japan and Northern China? Again, what but this far-reaching force of glacial action was it which caused the arctic plants to migrate from northern climates to inhabit the summits of such isolated peaks as Mount Washington in New Hampshire, and forced the persistent Scotch heather to leave its native heath and take up a lonely residence on the barren hills of Nantucket? And are not the cedars of Lebanon growing upon an ancient moraine of the glacial period?

But, one says, I am not particularly interested in botany: I am studying butterflies. Very well: you have not yet escaped the meshes of our net, for here you are with your butterflies attached to the triumphant car of glacial geology; for has not Mr. Scudder discovered a colony of arctic butterflies, on the very tops of the White Mountains, which could by no possibility have migrated thither except under the conditions furnished by the glacial period? And are not the relatives of these butterflies found in the Rocky Mountains and on the Alps, where they bear testimony to the same pervasive influence?

When the student of science is asked the utility of his investigations, it is sufficient to say, that they are justified by the additions they make to the mental furniture of the human race. They enrich the life of all the people who become cognizant of the new facts ascertained and the new principles established. To add a comprehensive thought or an important principle to the stock of the world's ideas is to increase the value of human life beyond the power of money to estimate. The world was made for other ends than the production of bread and butter. Man is endowed with measureless powers of thought and investigation, and the world is adapted to evoke those powers to their utmost, and to give to him the highest mental satisfaction.

The still wider scope of inductive reasoning, and the solid basis upon which it is founded, is illustrated in the recent advancement made in the study of zoölogy and botany, and here, as elsewhere in the realm of natural science, a remarkable adaptation is evident between the powers of the human mind and the field of investigation to which it is limited. The real meaning of modern scientific advancement is that, in the realm in which it is most manifest, we are getting nearer than ever before to the thoughts of the Creator. Nature is a realization of the thought of God, and it is by no means the astronomer only who thinks the thoughts of God after him. In an unscientific age men are contented to live in a world of their own creation, and to people the earth and sky with ghosts and hobgoblins, and to cower down in the presence of the occult forces of nature as though these forces were not held in restraint by the same arm that sustains the visible world.

The modern doctrine of the derivative origin of species is one of the most important additions to the mental furniture of the human race. To a greater extent than we are ordinarily aware, our mental processes depend upon the principle of the continuity of nature. So long as every species was thought to be of independent origin, and every organ of the plant or animal was looked upon as designed for present service in the organization, the study of botany and zoölogy yielded disappointing results, both to the system maker and to the student of natural theology. There was comparatively little satisfaction to a high-minded man in spending his days in the mere classification of different forms of plants and animals according to degree of resemblances. As closer attention was given, it became necessary to recognize newly discovered differences, and either to set up new species without number, or enlarge the definition of variety until it was about the same as species had heretofore been; while the student of natural theology was more and more puzzled to meet the demands made upon him in explaining the usefulness of rudimentary organs, and the benevolent design of the various imperfections in all the organs most essential to life. The assumption of the continuity of species was needed to give meaning to these troublesome facts in classification, to account for the apparent imperfections of organs both in structure and in function, and to give a reason for the many anomalous facts in the distribution of plants and animals both in time and space. But when once this higher conception of nature was furnished, all these inexplainable and anomalous facts became invested with intellectual grandeur. Innumerable things which, under the old style of reasoning, were inexplicable on account of our narrow views of design, take on now deep and real meaning.

For example, all so-called rudimentary organs have real meaning when viewed in the light of the continuity of species. The uncut rudimentary teeth of the new-born calf, the apparently harmful splint-bones of the horse's leg, the useless and sometimes dangerous vermiform appendix of the human stomach, and innumerable other such abortive organs, although so ill adapted to any present service in the organisms, are to the intellect of man an avenue through which comes a great enlargement of his mental horizon. These organs, though not of use now, have been of use in time past, and, as Darwin has suggested, are now of the highest use as an aid to the student of nature. Like the silent letters in a language, they are historical monuments of great value.

In all this adaptation to the intellectual wants of the human mind, the goodness of the Creator is too plain to be denied. God has not left us orphans in the world. He has indeed set us down in a most complicated labyrinth of natural forces; but he has provided us with all the clue that is necessary for its explanation, and given us the intelligence to use the clue successfully, if we will. The universe is not a trackless desert, in which man is left to find his way by guesswork, but rather a well-ordered country, amply provided with natural highways, and guide-boards pointing to all the desirable places of destination. The progress of modern science is a standing witness to this truth. The method of modern science is but a reflex of the method of the universe. The backwardness of the race in scientific attainments is due to their pride and prejudice. Instead of questioning nature for information, men have, until recent times, been content to frame great theories without regard to facts, and have amused themselves with telling how they thought the world ought to be built, rather than how it really is built. We are but just learning how condescending and instructive a teacher nature herself really is, if only we will interrogate her work. Whence can it come, that dead nature is our teacher in such far-off things as these, if she have not the same intelligent and benevolent author who has framed the constitution of the human mind?

Thirty centuries ago the Psalmist exclaimed:—

"When I consider thy heavens, the work of thy fingers,
The moon and stars, which thou hast ordained;
What is man, that thou art mindful of him?
And the son of man, that thou visitest him?"

The answer is sometimes thought to imply that this question involves the idea that man is a very humble and lowly creature. But both the question and the answer imply the very opposite of this. What is man? Why, says the Psalmist, according to the best translation, he is a being that is but little lower than God, and whom God has covered with glory and honor.

"Thou madest him to have dominion over the works of thy hands;
Thou hast put all things under his feet:
All sheep and oxen,
Yea, and the beast of the field;
The fowl of the air, and the fish of the sea,
Whatsoever passeth through the paths of the seas.
O Lord, our Lord,
How excellent is thy name in all the earth!"

The lordship of man over nature was provided for in the creation both of man and of nature. If David in his day marvelled at the extent of this lordship, what should be the admiration of the modern man of science when he sees the extent of this dominion increased so many thousand-fold! Man has already climbed to dizzy heights of knowledge, and is to ascend still higher, but it is on a mountain of God's own making. The same heavenly Father who clothes the lilies of the field with beauty, and feedeth the birds of the air, that toil not nor spin, has provided for the vast intellectual wants of the human race. In this adaptation, and in these remarkable provisions, lie the great arguments for the pervasive existence of design in the works of nature. Modern science is not tearing down the great argument for design, but is building it up in colossal proportions. If it is causing us to neglect some of the old arguments of Paley, it is on the same principle that an army possessed of Springfield rifles and Krupp guns thinks lightly of the bows and arrows and various flint implements of earlier days. Modern science is an inestimable witness not only to the sublime endowments of the human race, but to the benevolence of the Creator in so ordering his own steps in nature that a finite being could follow them.