

NATURAL SCIENCE AND RELIGION

TWO LECTURES, DELIVERED TO
THE THEOLOGICAL SCHOOL OF YALE
COLLEGE

By ASA GRAY

NEW YORK CHARLES SCRIBNER'S
SONS, 743 AND 745 BROADWAY

1880

LECTURE I. -SCIENTIFIC BELIEFS.

I AM invited to address you upon the relations of science to religion, -in reference, as I suppose, to those claims of natural science which have been thought to be antagonistic to supernatural religion, and to those assumptions connected with the Christian faith which scientific men in our day are disposed to question or to reject. While listening weekly-I hope with edification -to the sermons which it is my privilege and duty to hear, it has now and then occurred to me that it might be well if an occasional discourse could be addressed from the pews to the pulpit. But, until your invitation reached me, I had no idea that I should ever be called upon to put this passing thought into practice. I am sufficiently convinced already that the members of a profession know their own calling better than anyone else can know it; and in respect to the debatable land which lies along the borders of theology and natural science, and which as been harried by many a raid from both sides, I am not confident that I can be helpful in composing strifes or in the fixing of boundaries; nor that you will agree with me that some of the encounters were inevitable, and some of them alarm groundless. Indeed upon much that may have to say, I expect rather the charitable judgment than the full assent of those whose approbation I could most wish to win. But I take it for granted that you do not wish to hear an echo from the pulpit nor from the theological class-room. You ask a layman to speak from this desk because you would have a layman's thoughts, expressed from a layman's point of view; because you would know what a naturalist comes to think upon matters of common interest. And you would have him liberate his mind frankly, unconventionally, and with as little as may be of the technicalities of our several professions. Frankness is always commendable; but outspokenness upon delicate and unsettled

problems, in the ground of which, cherished convictions are rooted, ought to be tempered with consideration. Now I, as a lay-man, may claim a certain license in this regard; and any over-free handling of sensitive themes should compromise no one but myself. As a student who has devoted an ordinary lifetime to one branch of natural history, in which he is supposed to have accumulated a fair amount of particular experience and to have gained a general acquaintance with scientific methods and aims, -as one, moreover, who has taken kindly to the new turn of biological study in these latter years, but is free from partisanship, -I am asked to confer with other and younger students, of another kind of science, in respect to the tendencies of certain recently developed doctrines, which in schools of theology are almost everywhere spoken against, but which are everywhere permeating the lay mind- whether for good or for evil- and are raising questions more or less perplexing to all of us. But our younger and middle-aged men must not think that such perplexities and antagonisms have only recently begun. Some of them are very old; some are old questions transferred to new ground, in which they spring to rankness of growth, or sink their roots till they touch deeper issues than before, -issues of philosophy rather than of science, upon which the momentous question of theism or non-theism eventually turns. Some on the other hand are mere survivals, now troublesome only to those who are holding fast to theological positions, which the advance of actual knowledge has rendered untenable, but which they do not well know how to abandon; yet which, in principle, have mostly been abandoned already. To begin with trite examples. Among the questions which disquieted pious souls in my younger days, but which have ceased to disquiet any of us, are those respecting the age and gradual development of the earth and of the solar system, which came in with geology and modern astronomy. I remember the time when it was a mooted question whether geology and orthodox Christianity were compatible; and I suppose that when, in these quarters, the balance inclined to the affirmative, it was owing quite as much to Professor Silliman's transparent Christian character as to his scientific ability. One need not be an old man to know that Laplace was accounted an atheist because he developed the nebular hypothesis, and because of his remark that he had no need to postulate a Creator for the mathematical discussion of a physical theorem; for a venerable and most

religious astronomer, still living, who adopted this hypothesis in his "Exposition of certain Harmonies of the Solar System," published only five years ago, thought it needful to add an appendix, asking the question, "Is the nebular hypothesis, in any form, essentially atheistical in its character?" He answered it in the negative, but with the salvo, that "this hypothesis, having to do with a strictly azoic period, enforces no connection with the development theory of the beginning or of the progress of life." The great antiquity of the habitable world, and of existing races was the next question. It gave some anxiety fifty years ago; but is now, I suppose, generally acquiesced in, -in the sense that existing species of plants and animals have been in existence for many thousands of years; and, as to their associate, man, all agree that the length of his occupation is not at all measured by the generations of the biblical chronology, and are awaiting the result of an open discussion as to whether the earliest known traces of his presence are in quaternary or in the latest tertiary deposits. As connected with this class of questions, many of us remember the time when schemes for reconciling Genesis with Geology had an importance in the churches, and among thoughtful people, which few if any would now assign to them; when it was thought necessary -for only necessity could justify it -to bring the details of the two into agreement by extraneous suppositions and forced constructions of language, such as would now offend our critical and sometimes our moral sense. The change of view which we have witnessed amounts to this. Our predecessors implicitly held that Holy Scripture must somehow truly teach such natural science as it had occasion to refer to, or at least could never contradict it; while the most that is now intelligently claimed is, that the teachings of the two, properly understood, are not incompatible. We may take it to be the accepted idea that the Mosaic books were not handed down to us for our instruction in scientific knowledge, and that it is our duty to ground our scientific beliefs upon observation and inference, unmixed with considerations of a different order. Then, when fundamental principles of the cosmogony in Genesis are found to coincide with established facts and probable inferences, the coincidence has its value; and wherever the particulars are incongruous, the discrepancy does not distress us, I may add, does not concern us. I trust that the veneration rightly due to the Old Testament is not impaired by the ascertaining that the

Mosaic is not an original but a compiled cosmogony. Its glory is, that while its materials were the earlier property of the race, they were in this record purged of polytheism and Nature-worship, and impregnated with ideas which we suppose the world will never outgrow. For its fundamental note is, the declaration of one God, maker of heaven and earth, and of all things, visible and invisible, -a declaration which, if physical science is unable to establish, it is equally unable to overthrow. But, leaving aside for the present all questions of this sort, I proceed with the proper subject of this discourse; namely, the further changes in scientific belief, which have occurred within my own recollection, even since the time when I first aspired to authorship, now forty- five years ago. There will be no need to go much beyond the line of subjects which it has been my business to study, in order to bring before you, in a cursory review, not indeed all the disturbing topics of the time, but quite enough of them for our purpose. For the changes which we have to consider are all more or less connected with the evolutionary theories which are now uppermost in the popular mind. In this presentation, it is best to set them forth in their simplest or most general form, divested of all theological or philosophical considerations, which have been or may be attached to them. I should rather say, to some of them. For the foundations, or at least the buttresses, of the now prevalent doctrine of the derivative origin of species mainly rest upon researches independently made, without speculative bias, being the general contributions to biological science in this century; the results of which have been accepted as far as made out without apprehension or other than scientific controversy. Upon no one of these particular points has there been a completer change of view than upon the distinctness of the animal and vegetable kingdoms. The former conviction that these two kingdoms were wholly different in structure, in function, and in kind of life, was not seriously disturbed by the difficulties which the naturalist encountered when he undertook to define them. It was always understood that plants and animals, though completely contrasted in their higher representatives, approached each other very closely in their lower and simpler forms. But they were believed not to blend. It was implicitly supposed that every living thing was distinctively plant or animal; that there were real and profound differences between the two, if only they could be seized; and that increased powers of investigation-

microscopical and chemical- might be expected to discover them. This expectation has not been fulfilled. It is true that the ambiguities of a hundred years ago are settled now. The zoophytes are all remanded to their proper places, though the animal kingdom at first claimed more than belonged to it. But other, more recondite and insurmountable, difficulties arose in their place. The best, I am disposed to say the settled, opinion now is, that there are multitudinous forms which are not sufficiently differentiated to be distinctively either plant or animal, while, as respects ordinary plants and animals, the difficulty of laying down a definition has become far greater than ever before. In short, the animal and vegetable lines, diverging widely above, join below in a loop. Naturalists may help classification, but do not alter these facts; when they sever this loop arbitrarily at what they deem the lowest point, or when they cut away the whole loop, and form of it a separate kingdom -the Protista of Haeckel. The only objection to the latter is (that the definition of this tertium quid from plant on the one hand and animal on the other is equally impracticable. One difficulty is removed only to have two in its place. The fact is, that a new article has recently been added to the scientific creed, -the essential oneness of the two kingdoms of organic nature. I crave your patience while I enter somewhat into particulars. Not many years ago it was taught that plants and animals were composed of different materials: plants, of a chemical substance of three elements,- carbon, hydrogen, and oxygen; animals of one of four elements, nitrogen being added to the other three. The plant substance, named cellulose, because it formed the cell-walls, was supposed to constitute the whole vegetable fabric. It was known that all plants produced nitrogenous matter in the form of a compound of four elements; but this was thought to be merely a contained product, in a structureless condition, and to be not so much essential to the plant's life as to that of the animals which the plants nourished. It was known to be structure-building material for animals: it was not known to be essential plant-structure also. But it was soon ascertained that this quaternary matter of the animal body was chemically the same in the plant, was elaborated there, and only appropriated by the animal. Next it was found that it was physiologically and structurally the same in the plant, that it was the living part of the plant, that which manifested the life and did the work in vegetable as well as in

animal organisms. This substance, which is manifold in its forms and protean in its transformations, has, in its state of living matter, one physiological name which has become familiar, that of protoplasm. The statement that "protoplasm is the physical basis of life" must be accepted as true. As Professor Allman puts it, "wherever there is life, from its lowest to its highest manifestations, there is protoplasm; wherever there is protoplasm, there too is life," or has been. The cellulose or solid material which composes the bulk of a tree or herb did not produce the protoplasm contained in its living parts, as was formerly supposed, but the protoplasm produced the cellulose: the semi-liquid and mobile matter within produced the cell-walls which enclose it. The walls or solid parts are to the protoplasm what the shell is to the oyster. The contents not only preceded the protective, investment, but can exist and prosper apart from it, as many a mollusk does, as many a simple plant does throughout the earlier and most active period of its life. Indeed this slimy matter lives before and apart from any thing which can be called a living being. A formless, apparently diffuent and structureless mass is seen to exhibit the essential phenomena of life, - to move, to feed, to grow, to multiply. We have spoken of beings so low in the scale that the individuals throughout their whole existence are not sufficiently specialized to be distinctively plant or animal: yet these are definite in form and fixed in phase, are individual beings, though we may not determine to which kingdom they belong. But there is life in simpler shape,

"If shape it might be called that shape has none, Distinguishable in member, joint, or limb,"

there is vital activity in that which has not attained even the semblance of individuality. Little lumps of protoplasm are these, with outline in a state of perpetual change, divisible into two or three or more, or two or three combining into one mass, either way without hindering or altering their manifestations. This living matter - of which Bathybius, if there be a Bathybius, or if it be any thing more than protoplasm of sponges, is one example -is said to have nothing more than molecular structure. It would be safer to say that the microscope has as yet revealed no organic structure. The natural history of protoplasm has recently been well expounded by Professor Allman, late President of the British Association, a most judicious naturalist, of conservative tendency; and his address, which

you have read or should read, saves me from further details, and enables me to proceed to other evidences of the substantial oneness of the two kingdoms of organic nature. Cellulose makes up the bulk of a vegetable, and was thought to be its true element. But it is now known to be not even peculiar to it: it enters largely into the fabric of certain animals, not of the very lowest grade. Starch was equally regarded as a purely and characteristically vegetable production; and its presence, in ambiguous cases, has been taken as a test. But it follows the example of cellulose. Being a prepared material from which cellulose in the plant is made by a molecular change, we are not now surprised to learn that starch-grains of animal origin have been found. We cannot conceive any thing more characteristic of a vegetable than chlorophyll, the green of herbage; for in it the special work of the plant is done, - namely, the transformation of mineral matter into organic, under the light of the sun, this being the prerogative of vegetation. Now, not only does chlorophyll abound in many ambiguous microscopical organisms of fresh and salt water, which except for this would be taken for animals, but it has recently been detected in hydras and sea-anemones and planarias, which are as certainly animals as are oysters and clams. Nor can it be thought that they possess something merely resembling chlorophyll; for it performs the characteristic work of that peculiar substance, which, as I have said, is the characteristic work of vegetation. For the simultaneous and essential accompaniment of this work (i. e., of the conversion of mineral into organic matter) is the evolution of oxygen gas from the decomposition of carbonic acid, water, &c., in which, if in any thing, vegetation consists. Now, the proof that what these animals possess is chlorophyll itself is demonstrated by their performance of the same function. They decompose carbonic acid and evolve oxygen gas, just as a green leaf does. Moreover, the chlorophyll has been extracted and identified by the spectroscopic test. Here, then, animals, undoubted animals, in addition to their own proper functions, take on the essential function of plants. There is no avoiding the conclusion that such animals are doing the duty of vegetables. Although I make little account of it, I should not overlook a more empirical distinction between the two kingdoms which has also failed. The characteristic features of an animal were mouth and stomach. This is the normal correlation of an animal with its conditions. Having to feed on vegetable matter,

or what has been vegetable matter, in solid as well as liquid form, a mouth opening into an internal cavity of some sort was the natural pattern, to which all animals were supposed to conform. But Nature, with all her fondness for patterns, will not be arbitrarily held to them. Entozoa feed like rhizophytes; and turbellarians and their relatives have no alimentary canal, - the food taken by what answers to mouth passing as directly into the general tissue as does the material which a parasitic root imbibes from its host, or an ordinary root from the soil. While animals are thus overpassing the boundary in one direction, vegetables are making reprisals on the other. The rule is, that vegetables create organic matter, and animals consume it, producing none. But, while some animals produce some organic matter, some plants even among those of the highest grade feed wholly upon other plants, or even upon animals or their products. Like animals, some are herbivorous and some are carnivorous. That certain plants live parasitically upon other plants or upon animals, has long been too familiar to be remarkable. But that plants of the highest grade could capture or in some way take possession of small animals, extract and feed upon their juices, and appropriate these, as nourishment, is essentially a recent wonder and a recently ascertained fact. Yet some of the facts which point to this conclusion are old enough; and the conclusion would probably have been reached years ago, except for the preconception that plants and animals were too distinct for interchange of functions. Now that we know they are not, and that the living structure in the two is fundamentally identical, what were formerly regarded as freaks of Nature are no longer mere wonderments, but parts of a system, and capable of being correlated with the rest by investigation. And investigation soon ascertained that this carnivorous attachment to the vegetable organism in *Dionaea* and *Drosera* was an organ for digesting as well as capturing animal food. Juices are not imbibed by it directly, as in animals from the stomach; and nourishing solid parts are rendered soluble and assimilated by imbuing them with peptones or digestive ferments, analogous in composition and in action to the gastric juice of the higher animals. Perhaps nothing in Nature can be more wonderful than all this; and nothing is more characteristic of the change which has come over scientific mind in our day than the manner in which such a discovery is received. The leading facts were well known a hundred years ago, and more. But, until recently, these phenomena were regarded as

altogether anomalous; and such anomalies appear to have troubled no-body, except the framers of definitions. "Lusus natura" was a convenient phrase, and stood in the place of explanation, -as if the play of Nature was something apart from her work. No one seems to have had any difficulty in believing that a few particular plants were endowed with faculties of which no other plants were sharers. The thoughtful naturalist of our day is in a different frame of mind. He expects to find that the extraordinary is only an extreme case of the ordinary; and he looks for instances leading up from the one to the other. I cannot tarry to explain how this expectation has directed observation and stimulated research in this particular field, and reached the result that these wonderful plants are distinguished only by higher degrees and more prominent manifestations of a power which is in some sort common to many or to all their brethren. We learn, even, that the germinating embryo of a grain of corn feeds upon and digests the solid maternal nourishment which surrounds it, and the humblest mould appropriates the organic matter which it attacks, by the aid of a peptone or inversive ferment, not different in nature and -office from the gastric and other juices by aid of which we appropriate our daily meals. It does appear also that the lowest organisms, which live a kind of scavenger life, by using over again dead or effete organic matter running to decay -but to some of which living juices come not amiss -have also the power, certain salts being given, of creating organic matter, and building up a fabric without sun-light and without chlorophyll. Here, then, is the simplest organic life, -in which, germs being given, i. e. first individuals of the sort supplied and placed in favorable surroundings, they increase and multiply into more, each to multiply again, and so on, in geometrical progression. From such lowly basis the two kingdoms may be conceived to rise, diverging as they ascend in separate lines, -the one developing close relations with sunlight and becoming the food-producing vegetable realm; the other, the food-consuming animal realm, which, dispensed from the labor of assimilation, and from the fixity of position which generally attends it, may rise to higher and freer manifestations of life. Such, at least, appear to be the relations of the two kingdoms to each other and to their common base; and such is the conception through which we may attain to an explanation of how it may be that members of each line possess so many characteristics of the

other. I have said, "germs being given," the forms increase and multiply. If asked, Whence the germs, and were they everywhere and always prerequisite? the scientific answer must be yes, so far as we know. Thus far, spontaneous generation, or abiogenesis, -the incoming of life apart from that which is living, -is not supported by any unequivocal evidence, though not a little may be said in its favor. However it may be in the future, here scientific belief stands mainly where it did forty-five years ago, only on a better-trying and firmer footing. It remains to mention two supposed distinctions between vegetables and animals which were until recently prominent, but which are no longer criteria, even as between the higher forms of the two. The first is the faculty of automatic movement, or -to take up the question only on the highest plane -the faculty of making movements in reference to ends. This is affirmed of animals, and is an undoubted faculty of all of them, but was long denied to plants, perhaps from a notion that such movements argued consciousness. But consciousness, in any legitimate sense of the term, pertains only to the higher animals. To show the breaking down of the distinction, it would suffice to contrast the rooted fixity and vegetative growth of very many lower animals with the free loco-motion of most microscopic aquatic plants and of the genus of those not microscopic; but plants of the highest organization furnish obvious "examples better suited to our purpose. Is there not an independent movement, in response to an external impression, and in reference to an end, when the two sides of the trap of *Dionaea* suddenly enclose an alighted fly, cross their fringe of marginal bristles over the only avenue of escape, remain quiescent in this position long enough to give a small fly full opportunity to crawl out, soon open if this happens, but after due interval shut down firmly upon one of greater size which cannot get out, then pour out digestive juices, and in due time re-absorb the whole? So, when the free end of a twining stem, or the whole length of a tendril, outreaches horizontally and makes circular sweeps, and secures thereby a support, to which it clings by coiling; when a tendril, having fixed its tip to a distant support, shortens itself by coiling, so bringing the next tendril nearer the support; when a free revolving tendril avoids winding up itself uselessly around the stem it belongs to, and ill the only practicable way, namely, by changing from the horizontal to the vertical position until it passes by it, and then rapidly resumes its horizontal sweep, to result in

reaching a distant support, -is it possible to think that these are not movements in reference to ends? You may say that all such movements are capable of explanation, or in time will be so; are the result of mechanism, and adjustments, and of common physical forces. No doubt; and this is equally true of every animal movement, not excepting those instigated by volition. "Still it moves," as the humbled Galileo said of the earth; and the idea that such movements are in reference to ends is not superseded by any yet devised explanation of the mechanism. A remaining distinction between plants and animals was based on the relations they respectively sustain to the air we breathe. This has already been stated, and the exceptions noted; but the topic is resumed in order to bring to view the substantially different relations of the two kingdoms to physical force. Plants give out oxygen gas, and thus purify the air or the respiration of animals. Animals, consuming this oxygen, breathe it back to the air in the form of carbonic acid. But the putting of this contrast is only another way of saying that plants produce organic matter and animals decompose it. The oxygen gas given out by sun-lit foliage is just what is left over when carbonic acid is decomposed and the carbon enters into the composition of the vegetable matter then produced. This elaborated matter, more complex and unstable than the materials of which it was made, is the food of animals, is first appropriated, then decomposed by them, and in the decomposition the carbon is given back to the air recombined with the oxygen they inhale, the carbon again taking the oxygen which was separated from it by the plant. So respiration means decomposition; and this decomposition in the animal economy means organic material used up, work done, energy degraded. It means that the clock-weight which was wound up by the sun in the plant has run down. It means that, very much as the sun, shining on the earth and ocean, converts water into vapor and lifts it into the upper air, so the same luminary, shining upon the plant, there raises mineral matter to a higher and unstable state, in what we call organic products, - in both cases endowing the affected matter with a certain energy. The exalted matter in the one case falls at length as rain, perhaps directly into the ocean from which it was lifted, perhaps upon a mountain summit, where as snow or glacier-ice it may long remain poised and comparatively stationary. But sooner or later it falls into the rivulet and the river, and in its fall and flow it expends its endowment of energy, and does

work, -turns wheels and spins or forges, if man so directs, -and, when it has reached stable equilibrium at the level of the ocean, it will have expended just the energy which was imparted to it in the raising. So the energy with which the sun endowed vegetable matter when it was raised to the organic state may be given up as heat when this matter is restored to its original condition by burning, or falls slowly back to the same condition in the process of natural decay; or the heat, like the falling water, may do mechanical work. But also the organic material may be consumed in the plant itself. For the plant, like the animal, is a consumer. The only difference is that, whereas the animal is always and only a consumer and decomposer, the plant creates or composes likewise, and it produces vastly more than it consumes or decomposes. It decomposes only when it does mechanical work. But all its processes, all movements; all transformations, are work done at the expense of organized material and accumulated energy. Even the act of storing up solar force in the green herbage, or rather the changes connected with it, can only be done at a certain cost, though the cost is small in comparison with the gain. But every transference of material from one place or one state to another is done only by the decomposition and loss of some portion of it, - one part suffering that another may be changed and saved. When the germ feeds upon the maternal store in the seed, a considerable part is consumed in order to make the rest available; and the loss is made manifest, just M in the breathing of an animal or in the combustion of fuel, by the evolution of carbonic acid and of heat. The same thing in its measure occurs in the upbuilding of the fabric, the carrying of material high into the air, -into a tree-top, for instance; and in all the processes of flowering, and in storing up in the seed the richest products as an outfit for a new generation. Where visible movements take place, the quicker action is at equivalent cost. The sensitive tendril, which will coil promptly after the first brushing with my finger, will coil again only after an interval of rest, and upon the third or fourth excitation, or after a certain number of spontaneous revolutions, it falls exhausted. But material endowed with energy in the plant is largely transferred as food to animals. It brings to them an energy which they may use, but did not originate. Not many years ago, it was taken for granted that living things moved and had their being, and did their work, by strength of their own; that the power by which I strike a blow, or

write on my paper, or move my lips in articulate speech, was somehow an original contribution to, rather than a directed use of, the common forces of physical nature. To all who have familiarized themselves with the facts of the case, the contrary is now substantially certain. The sun is the source of all motion and force manifested in life on the earth, and plants are the medium in which energy is exalted to the most serviceable state. The work done by living beings is at the expense of, and is measured by, the passage of so much matter from an unstable to a relatively stable equilibrium, by the coming together of molecules in to closer and; firmer positions, and by the attendant fall of so much energy from an exalted to a relatively degraded condition. So plants, animals, men, in all their doings, add nothing to and take nothing from the sum of physical force. Their prerogative is, each in its measure, to direct the application of physical force, and to direct it to ends. The idea of ends involves that of individuality. The higher animals, and men among them, are complete individuals. We cannot make the idea of individuality any clearer than by adducing them as examples of it. In the lowest form of life, in those amorphous or indefinitely polymorphous "little lumps of protoplasm" which the biologists have made known to us, and even, perhaps, in a stratum or mass which takes the form of whatever bounds it, it is said that we may contemplate the phenomena of life in that which has no manifest individuality. What have we between these two extremes? The first and simplest individuality is that of cells. Cell-doctrine, or the cellular composition of plants and animals, belongs wholly to the biological science of the last half-century, although the name is older, and some knowledge of the structure in plants is as old as the micro-scope. The homologizing of animals with plants in this regard began about forty years ago; and the doctrine of the individual life of cells is recent. Unfortunately the rather inappropriate name cell came into use before the structure was rightly understood, and may be misleading. It was given, naturally enough, to the walls circumscribing cavities in ordinary plant-tissue, before it was understood that the walls were not made and then filled, -before it was known that the contents are the living thing, and the wall an encasement or shell. The substance of our recent knowledge is, -that a plant is an aggregate of organic units, mostly of very small size; that these are to the herb or tree what the bricks and stones of this chapel are to the edifice. Only

they" are living stones, fitly framed together" in organic growth, and their walls answer to the cement. Animals do not differ materially, except that the mortar is mostly of the same nature as the bricks, and there is a greater or at length complete fusion or confluence of the cells. The component material, the protoplasm, is essentially the same, as has already been stated. But each aggregate, each ordinary plant or animal, begins as one cell, which is then the simple individual. This is growth and propagation divides itself into two, these two into four, these into sixteen, and so on, thus building up the structure, -a whole, of which the individual cells are component parts. The simplest plant begins in the same way with an initial cell, but this, instead of multiplying with cohesion into a structure, multiplies with separation into progeny. Other simple plants go on without separation to form a row of similar cells, which may casually fall apart into individuals or may remain connected; but in either case each has its own life, and does what the others do, so that the separation or the continued connection is a matter of indifference. But when, higher in the scale, structures are built up, what were individuals become parts or organs, or the thousandth or millionth part of an organ; then the life of the cells is their own no less, but their individuality blends in the common life of the aggregate. By increasing complexity of organization, with increasing subordination of parts and specialization of office, the highest plants and animals are composed. In them each unit or cell has its own life and its own nutrition, while also contributing to the common weal, -some by this function, some by that; but in the higher forms all are somehow controlled by a pervasive life and directed to common ends, -ends the more various, complex, and special, in proportion to the rank of the organism in the scale of being. So, too, the component cells become effete and die, while the aggregate life continues; and the continued structure, which is nothing but an aggregate, is somehow informed, animated, and operated by a common life of higher grade than that of any or all its components. In numerous lower plants and animals we cannot definitely determine what are organisms and what are organs; in the herb or tree, and in the coral polypidom, organ, individual, colony are inextricably blended; in the higher animals subordination of parts to a whole is completely attained. All along the ascent that which controls and subordinates parts aggrandizes its

manifestations. The lowest animals add very little to merely vegetative life, except greater sensitiveness to external impressions and more free and varied response; a step higher brings in a greater range of unconscious feeling; the higher brute animals have attained unto specific desires, affections, imagination, and the elements of simple thought; the highest, gifted with reflective reason, may make their own thoughts the subject of thought. So, our conception of individuality is from ourselves, conscious beings: it is carried down unqualified to the brute animals with which we are associated; it becomes vague and shadowy in plants, but still, somehow, the idea inheres throughout all organisms. The beginning of organization is individuation or tendency to individualize. The completed self is man. Here let me interject a remark in correction of a common misapprehension as regards the nature of the simplicity of the lowest organisms. An animalcule and a unicellular plant, or the cellular components of common plants or animals, are simple indeed, comparatively. But the recent science which has brought out the close connection of the lower with the higher forms (and showed that through all "one increasing purpose runs ") is also showing, in all the latest microscopic work, that the plant-cell and the animal-cell are really very complex structures, and the processes through which one cell becomes two, instead of being a simple bisection, prove to be very elaborate and wonderful. The further the investigation is carried under the modern microscope, the more complex and recondite does their structure and behavior appear to be. They seemed to be simple because they are small; but much of the simplicity vanishes upon intimate acquaintance. Wherefore, in view of recent discoveries of this sort, it is premature to conclude that the "little lumps of protoplasm" described by Haeckel are really destitute of organic structure. It is an illusion to fancy that the mystery of life is less in an amoeba or a blood-corpuscule than in a man. From individuals in themselves, let us pass to questions relating to their succession and kinds. Plants and animals, each propagating their kind, produce lines of individuals, sustaining to each other the relation of parent and progeny. These lines are the species of the naturalist. Have the species come down from the beginning of life, unaltered or altered; or have there been successive creations? Taking first the vegetable and animal kingdoms as a whole, it has long been well understood that ages upon ages have passed since the earth was stocked with living

beings of numerous sorts. Kind after kind has appeared, flourished, and disappeared; and, in the long succession, species of progressively higher rank have come into existence, the forms more and more approximating those which now exist. There is good reason to believe that at more than one epoch the earth has been as fully stocked with species as it is now, and in equal diversity, except as to the highest types. What relation have these beings of the earlier and of the succeeding times sustained to each other and to the present inhabitants of the earth? Half a century ago; when I began to read scientific books and journals, the commonly received doctrine was, that the earth had been completely depopulated and repopulated over and over, each time with a distinct population; and that the species which now, along with man, occupy the present surface of the earth, belong to an ultimate and independent creation, having an Ideal but no genealogical connection with those that preceded. This view, as a rounded whole and in all its essential elements, has very recently disappeared from science. It died a royal death with Agassiz, who maintained it with all his great ability, as long as it was tenable. I am not aware that it now has any scientific upholder. It is certain that there has been no absolute severance of the present from the nearer past; for while some species have taken the place of other species, not a few have survived unchanged, or almost unchanged. And, it is most probable that this holds throughout; for certain species appear to have bridged the intervals between successive epochs all along the line, surviving from one to another, and justifying the inference that species -however originated -have come in and gone out one by one, and that probably no universal catastrophe has ever blotted out life from the earth. Life seems to have gone on, through many and great vicissitudes, now with losses, now with renewals, and everywhere at length with change; but from first to last it has inhered in one system of nature, one vegetable and one animal kingdom, which themselves show indications of a common starting-point. As respects the vegetation, from which I should naturally draw illustrations, the nature and amount of the likeness between the existing flora and that of a preceding geological period has recently been summed up by Saporta in the statement that there is not a tree nor a shrub in Europe or North America which has not recognizable relatives in the fossil remains of the tertiary period. It is like visiting a country church-yard, where "The rude forefathers of the hamlet sleep," and spelling out,

one by one, from mossed and broken gravestones, the names of most of the living inhabitants of the parish, -names differing it may be in orthography from those on the village signs; but, as of the people, so of the trees, it is beyond reasonable doubt that the later are descendants of the earlier., The same holds true of animals; and the facts therefore point toward the conclusion that existing species in general are descended from tertiary ancestors. But if so they have mostly undergone change, and great change as we go farther back with the comparison. And there are many existing forms of which no fossil ancestor is known. What relation, if any, can these sustain to a by-gone flora or fauna? And, with what reason do we predicate change of species in former times if they are not changeable now? This brings up the question of the fixity or variability of species. Scientific opinion upon this point is not what it was thirty or forty years ago. Then it was generally, though not universally, believed that species are perfectly definite and stable; capable of variation, indeed, but only within circumscribed limits. Wherever it was difficult or impracticable to discriminate them, the difficulty was presumed to be, not in the things themselves, but in the imperfection of the naturalist's knowledge or acumen. There was the evidence of a good number of cases to show that species had not perceptibly altered in four or five thousand years, and of some having lasted for a vastly longer time. Hence it was an article of scientific faith that species on the whole were fixed now, and that probably they have come down essentially unaltered from the beginning,- a beginning which was wholly beyond the ken and scope of science, which is concerned with questions about how things go on, and has nothing to say as to how they absolutely began. The naturalists of that day might suppose - certainly many of them did suppose -that existing species may have come into being by other than direct supernatural origination, and, indeed, the foremost of them were well aware that the "question of origin would have to be reargued at no distant day. But, so far, the various speculative attempts at explaining the mystery of the incoming of species had not been encouraging, and eminent naturalists deprecated all general theories of the sort, as at the best a waste of time. So the fixity and inscrutability of species -though silently doubted by some, and controverted by a few was still the postulate of natural history; and more than one laborious naturalist has been known to declare that, if this fixity was not complete, natural

history was not worth pursuing as a science. There is now a different attitude toward this class of questions. First, the absoluteness of species is no longer taken for granted. That species have a stability, that every form reproduces after its kind, is obvious; but it is equally obvious that the similarity of its individuals is not complete. It had been assumed that the differences brought about by variation are always comparatively small, unessential, and limited. This is now partly doubted, and partly explained away. In the first place, much of the popular idea of the distinctness of all species rests on a fallacy, which is obvious enough when once pointed out. In systematic works, every plant and animal must be referred to some species, every species is described by such and such marks, and in the books one species is as good as another. The absoluteness of species, being the postulate of the science, was taken for granted to begin with; and so all the forms which have been named and admitted into the systematic works as species, are thereby assumed to be completely distinct. All the doubts and uncertainties which may have embarrassed the naturalist when he proposed or admitted a particular species, the nice balancing of the probabilities and the hesitating character of the judgment, either do not appear at all in the record or are overlooked by all but the critical student. Whether the form under consideration should be regarded as a new species, or should be combined with others into a more generalized and variable species, is a question which a naturalist has to decide for the time being, often upon insufficient and always upon incomplete knowledge; and increasing knowledge and wider observation generally raise full as many doubts as they settle. This may not be so decidedly the case in zoology as in botany; but I incline to the opinion that there is no wide difference in this respect. The patient and plodding botanist spends much of his time in the endeavor to draw specific lines between the parts of a series the extremes of which are patently different, while the means seem to fill the interval. When he is addressed by the triumphant popular argument, "if one form and f one species has been derived from another, show us the intermediate forms which prove it," he can only ejaculate his wish that this ideal vegetable kingdom was the one he had to deal with. Moreover when he shows the connecting links, he is told, "Then these are all varieties .of one species; species are fixed, only with wider variation than was thought." And when he points to the wide difference between the extremes, as

being greater than that between undoubted species, he is met with the rejoinder, "Then here are two or three or more species which undoubtedly have true distinctions, if only you would find them out." That is quite possible, but it is hardly possible that such fine differences are supernatural. Some one when asked if he believed in ghosts, replied, No, he had seen too many of them. So I have been at the making and unmaking of far too many species to retain any overweening confidence in their definiteness and stability. I believe in them, certainly. I do not exactly agree that they "are shadows, not 'substantial things," but I believe that they have only a relative fixity and permanence. You will ask if lack of capacity to interbreed is not a criterion of species. I must answer, No. As a matter of course individuals of widely diverse species cannot interbreed; those of related species not uncommonly do; but it is said that when they do interbreed the hybrid progeny is sterile. Commonly it is so, sometimes not. The rule is not sufficiently true to serve as a test, either in the vegetable or in the animal kingdom. The only practical use of the test is for the discrimination of the higher grade of varieties from species. Now in fact some varieties of the same species will hardly interbreed at all; while some species interbreed most freely, and produce fully fertile offspring. So the supposed criterion fails in the only cases in which it could be of service. All that can be said is, that whereas known varieties tend to interbreed with unimpaired and sometimes with increased fertility, distinct species of near resemblance tend not to interbreed at all; and between the two extremes there are all intermediate conditions. Here, as throughout organic nature, the extremes are far apart; the interval is filled with gradations. What then is the substantial difference between varieties and species? Just here is the turning-point between the former view and the present. The former doctrine was that varieties come about in the course of nature, but species not; that varieties became what they are, but that species were originally made what they are. I suppose that, even before the day of Darwinism, most working naturalists were reaching the conviction that this distinction was untenable; that the same rule was applicable to both; and therefore that either varieties did not come in the course of nature, or that species did. Perfectly apprehending the alternative and its consequences, Agassiz took the ground that varieties as well as species were primordial, or rather that the more marked forms called

varieties by most naturalists were species, and therefore original creations. Rightly to understand his view, it must be taken along with his conception of species, as consisting from the very first of a multitude of individuals. Other naturalists were looking to the opposite alternative, and were coming to the conclusion that species as well as varieties were natural developments. In botany, this conclusion was reached more than sixty years ago, through observation and experiment, by an English clergyman and naturalist, Herbert, afterward Dean of Manchester. He announced his conviction that "horticultural experiments have established, beyond the possibility of doubt, that botanical species are only a higher and more permanent class of varieties," and, consequently, that the genus is the progenitor of the species belonging to it. Others have reached the same conclusion by more speculative routes, and have deduced the theoretical consequences. But no marked impression was made until the hypothesis of natural selection, or the preservation of favored races in the struggle for life was promulgated, and supplied a scientific reason for the diversification of varieties into species. The principle brought to view is too obvious to have been wholly overlooked. It is interesting to notice: that the earliest known anticipation of that principle which Darwin and Wallace developed almost simultaneously, was published sixty years ago, by Dr. Wells, the sagacious author of the theory of dew, who hit upon the idea of natural selection while resident in America. As abstracted by Mr. Darwin, who evidently takes delight in the discovery of these anticipations, the points which Dr. Wells made were substantially these: - All animals vary more or less: agriculturists improve domesticated animals by selection." What is thus done by art is done with equal efficacy, though more slowly, by Nature, in the formation of varieties of mankind, fitted for the country which they inhabit, and in this way: Negroes and mulattoes enjoy immunity from certain tropical diseases, and white men a comparative immunity from those of cold climates. Under the variation common to all animals, some of the darker would be better adapted than the rest to bear the diseases of a warm country, -say of tropical Africa. This race would consequently multiply, while the others would decrease, directly, because the prevalent diseases would be more fatal to them, and indirectly, by inability to contend with their more vigorous neighbors. Through the continued operation of the same

causes, darker and darker races would prevail over the less' dark, and in time would monopolize the region where they originated or into which they had advanced. Similarly would white races, to the exclusion of dark, be developed and prevail in cooler regions. Now, this simple principle, -extended from races to species; from the present to geological ages; from man and domesticated animals to all animals and plants; from struggle with disease to struggle for food, for room, and against the diverse hardships which at times beset all living things, and which are intensified by the Malthusian law of the pressure of population on subsistence, -population tending to multiply in geometrical progression, while food can increase only in a much lower ratio, and room may not be increasable at all, so that out of multitudinous progeny only the few fittest to the special circumstances in each generation can possibly survive and propagate, -this is Darwinism; that is, Darwinism pure and simple, free from all speculative accretions. Here, it may be remarked that natural selection by itself is not an hypothesis, nor even a theory. It is a truth, -a catena of facts and direct inferences from facts. As has been happily said, it is a truth of the same kind as that which we enunciate in saying that round stones will roll down a hill further than flat ones. There is no doubt that natural selection operates; the open question is, what do its operations amount to. The hypothesis based on this principle is, that the struggle for life and survival of only the fittest among individuals, all disposed to vary and no two exactly alike, will account for the diversification of the species and forms of vegetable and animal life, -will even account for the rise, in the course of countless ages, from simpler and lower to higher and more specialized living beings. We need not here enter into any further explanation of this now familiar but not always well-understood hypothesis; nor need I here pronounce any judgment of my own upon it. No doubt it may account for much which has not received other scientific explanation; and Mr. Darwin is not the man to claim that it will account for every thing. But before we can judge at all of its capabilities, we need clearly to understand what is contained in the hypothesis; for what can be got out of it, in the way of explanation, depends upon what has gone into it. So certain discriminations should here be attended to. Natural selection we understand to be a sort of personification or generalized expression for the processes and the results of

the whole interplay of living things on the earth with their inorganic surroundings and with each other. The hypothesis asserts that these may account, not for the introduction of life, but for its diversification into the forms and kinds which we now behold. This, I suppose, is tantamount .to asserting that the differences between one species and another now existing, and between these and their predecessors, has come to pass in the course of Nature; that is, without miracle. In these days, all agree that a scientific inquiry whether this may be so -that is, whether there are probable grounds for believing it (no thoughtful person expects to prove it) -is perfectly legitimate; and, so far as it becomes probable, I imagine that you might safely accept it. For the hypothesis, in its normal and simplest form,- when kept close to the facts, and free from extraneous assumptions -is merely this:- Given the observed capacity for variation as an inexhaustible factor, assuming that what has varied is still prone to vary (and there are grounds for the assumption), and natural selection will- so to say-pick out for preservation the fittest forms for particular surroundings, lead on and diversify them, and, by continual elimination of the less fit, segregate the survivors into distinct species. This, you see, assumes, and does not account for, the impulse to variation, assumes that variation is an inherent and universal capacity, and is the efficient cause of all the diversity; while natural selection is the proximate cause of it. So it is the selection, not the creation of forms that is accounted for. Darwinism does not so much explain why we have the actual forms, as it does why we have only these and not all intermediate forms, -in short, why we have species. There is of course a cause for the variation. Nobody supposes that any thing changes without a cause; and there is no reason for thinking that proximate causes of variation may not come to be known; but we hardly know the conditions, still less the causes now. The point I wish to make here is that natural selection -however you expand its meaning -cannot be invoked as the cause of that upon which it operates, i. e., variation. Otherwise, if by natural selection is meant the totality of all the known and unknown causes of whatever comes to pass in organic nature, then the term is no longer an allowable personification, but a sheer abstraction, which meaning every thing, can explain nothing. It is like saying that whatever happens is the cause of whatever comes to pass. We may conclude, therefore, that natural selection, in the sense of

the originator of the term, and in the only congruous sense, stands for the influence of inorganic nature upon living things, along with the influence of these upon each other; and that what it purports to account for is the picking out, from the multitude of incipient variations, of the few which are to survive, and which thereby acquire distinctness. There is a further assumption in the hypothesis which must not be overlooked; namely, that the variation of plants and animals, out of which so much comes, is indefinite or all-directioned and accidental. This, I would insist, is no fundamental part of the hypothesis of the derivation of species, and is clearly no part of the principle of natural selection. But it is an assumption which Mr. Darwin judges to be warranted by the facts, and in some of its elements it is unavoidable. Evidently if the innate tendency to vary upon which physical circumstances operate is indefinite, then the variations which the circumstances elicit, and which could not otherwise amount to any thing, must be accidental in the same sense as are the circumstances themselves. Out of this would immediately rise the question as to what can be the foundation and beginning of this long and wonderful chapter of accidents which has produced and maintained, not only for this time but through all biological periods, an ever-varying yet ever well-adapted cosmos. But the facts, so far as I can judge, do not support the assumption of every-sided and indiffer-ent variation. Variation is somehow and somewhere introduced in the transit from parent to offspring. The actual variations displayed by the progeny of a particular plant or animal may differ much in grade, and tend in more than one direction, but in fact they do not appear to tend in many directions. It is generally agreed that the variation is from within, is an internal response to external impressions. All that we can possibly know of the nature of the inherent tendency to vary must be gathered from the facts of the response. And these, I judge, are not such as to require or support the assumption of a tendency to wholly vague and all-directioned variation. Let us here correct a common impression that Darwinian evolution predicates actual or necessary variation of all existing species, and counts that the variation must be in some definite ratio to the time. That is not the idea, nor the fact. "Evolution is not a course of hap-hazard and incessant change, but a continuing re-adjustment, which may or may not, according to circumstances, involve

considerable changes in a given time." Every form is in a relatively stable equilibrium, else it would not exist. Forms adjusted to their surroundings ought by the hypothesis to remain unchanged until the circumstances change. Only those of their variations could come to any thing which happened to be equally well adapted to the unchanged circumstances; and this may be what we have when two or more nearly related species inhabit similar stations in the same area. From this point of view you see how wide of the mark are those who imagine that Darwinian evolution supposes that the organic world was in early times, or at any time, out of joint or in ill relations to the surroundings. On the contrary, it is of the very nature of natural selection, that, while inducing changes eventually immense, it should preserve throughout all time a condition of harmonious adaptation. Catastrophes must destroy; but gradual modification, under the long and silent struggle which never hastes and never rests, preserves while it renovates and diversifies the races. I ought here to state that there are eminent naturalists (one of them of my own university) who accept the doctrine of evolution, but who think little of natural selection as a modus operandi in the diversification of species; and there are distinguished writers, not naturalists, who, from other points of view are ready to accept "the doctrine of the successive evolution from ancestral germs of higher and higher forms of life and mind," while they profess to have buried the principle of natural selection and with it the Malthusian theory of population in one common grave. These are evolutionists, in their way, because the probability of evolutionary theories springs from the very various lines of facts, otherwise inexplicable, which they harmonize and explain: -in geology, the previous existence of forms more and more like those now existing, and at length coalescing in them; in geography, the actual distribution of species and genera over the earth's surface; in systematic natural history, the reason why species and genera and orders are so variously related, are here connected by transitions and there separated by wide gaps; in morphology why the same functions may be assumed by different organs, or the same kind of organ may perform here one function and there another, or again exist as a vestige, of no service at all; in anatomy and biology, the transition from one element of structure to another, the gradual specialization of organs, and the remarkable coincidence between the order of the development in the individual animal and that of

the rise from low to high in the scale of being, and that of the successive appearance of the grades in time; finally in psychology, the gradations between beings endowed with rudimentary sensation and beings endowed with mind. Here, where the "touch of Nature makes the whole world kin," we reach the sensitive point. Man, while on the one side a wholly exceptional being, is on the other an object of natural history, -a part of the animal kingdom. If you agree with Quatrefages that man is a kingdom by himself, you must agree with him that this' kingdom is solely intellectual; that he is as certainly and completely an animal as he is certainly something more. We are sharers not only of animal but of vegetable life, sharers with the higher brute animals in common instincts and feelings and affections. It seems to me that there is a sort of meanness in the wish to ignore the tie. I fancy that human beings may be more humane when they realize that, as their' dependent associates live a life in which man has! a share, so they have rights which man is bound to respect. Man, in short, is a partaker of the natural as well as of the spiritual. And the evolutionist may say with the apostle: "Howbeit that was not first which is spiritual, but that which is natural, and afterward that which is spiritual." Man, "formed of the dust of the ground," endowed with "the breath of life," "became a living soul." Is there any warrant for affirming that these processes were instantaneous? As has just been intimated, the characteristic of that particular theory of evolution which is now in the ascendant is that, by taking advantage of "every creature's best" for bettering conditions, it has made strife work for good, throughout" an immensely long line of adjustments and readjustments, in a series ascending as it advanced; that it supposes a process, not from discord to harmony, but from simpler to fuller and richer harmonies, conserving throughout the best adaptations to the then existing conditions. So while its advocates nowhere contemplate a state

"When Nature underneath a heap,
Of jarring atoms lay,
And could not heave her head,"

they may appropriate Dryden's closing lines,-

"From harmony, from heavenly harmony,
This universal frame began,
From harmony to harmony
Through all the compass of the notes it ran,
The diapason closing full in man."

I have now indicated, at more than sufficient length for one discourse, some of the principal recent changes and present tendencies in scientific belief, especially in biology. Even the most advanced of the views here presented are held by very many scientific men, -some as established truths, some as probable opinions. There is a class, moreover, by whom all these scientific theories, and more are held as ascertained facts, and as the basis of philosophical inferences which strike at the root of theistic beliefs. It remains to consider what attitude thoughtful men and Christian believers should take respecting them, and how they stand related to beliefs of another order. That will be the topic of a following lecture.