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THE PRESENT RIGHTS AND DUTIES OF SCIENCE.

THE great truth underlying the subject of this paper is that every thing human has its ethical aspect. A stone, a brick-bat, an ounce of dynamite, or an ounce of gold, may in itself be absolutely unconnected with the domain of morals; but so soon as it comes into human hands questions of right and duty cluster round it. If this is true of merely material things, still more is it true of operations of mind. Every thought, every imagination, every conclusion, has direct relations with the moral nature as well as with the intellect. It becomes us, then, in viewing the materials of our modern civilization and social systems, to regard them from this point of view, and not to allow any great power to be abroad in the world without questioning it as to its duties and ascertaining what are its rights. It is in this ethical aspect that I desire for a little to regard the developments of modern science.

Science is a term of wide application, and may include any of those subjects of human thought in which facts are systematically arranged and referred to definite general principles. I propose here to take a narrower range, and to restrict myself to those sciences which relate to matter and force—the physical and biological sciences. Not that, with one of our modern schools of thought, I regard these as including all science worthy of the name, but because these have in our times attained a growth so vast, and have come to bulk so largely in the eyes of men as agencies for good or evil.

The rapid advance of precise knowledge and of inductive results with reference to matter and the energy which actuates it, and the myriad applications of this knowledge to the arts and

utilities of life, constitute indeed one of the main features of our time—one by which it is markedly distinguished from bygone ages, and one by which it will probably be characterized in the estimates formed of it by ages to come.

The cultivators of science have also come to be a most important class, even in numbers, and in influence greatly more important; and while on the one hand they appear as patient, self-denying plodders, toiling for the good of their fellows, on the other they become aggressive and troublesome when they attempt too rudely to explode our old ideas or to change our old ways.

What duties, then, does society owe to science and its cultivators, and what reciprocal rights devolve on them? Or, to put it in the converse way, What are the rights of science in relation to society, and what its duties to society in return?

With reference to its *rights*, science has fared very differently in different periods. In the dawn of civilization we can see in Chaldea and in Egypt bodies of learned men sheltering their scientific pursuits under the garb of religion, and cultivating, as a means of securing consideration, no little charlatanry in the form of astrology and divination. Yet these adventitious claims were sometimes dangerous as well as profitable. If the magi of Babylon had not mixed up their science with the forecasting of events and the interpretations of dreams, Nebuchadnezzar would not have condemned them to be slain and their houses made a dunghill. It is not to be concealed that similar baseless pretensions may still produce conflicts between science and other powers in society.

In the Græco-Roman period, with a few exceptions, among which Aristotle stands pre-eminent, science wandered from the safe paths of accurate investigation into those of speculative philosophy, prematurely grasping at the ultimate explanations of things; and so lost credit and cultivated opposition and contempt. We shall see that still the same tendencies produce like results.

The Arabian science, one-sided and unequal, and never penetrating the mass of the people, owed whatever it possessed of good to the inheritance of the practical culture of the East as distinguished from the speculations of Greece. Short-lived and leaving only a few brilliant results, it has at one time been unfairly overlooked and at another unduly exalted.

In the Middle Ages, amidst the expiring agonies of an old world and the birth of a new, the dread realities of life and death pressed too heavily on men's minds to permit much scientific activity, and caused them to cling to civil and ecclesiastical despotisms subversive of free thought and fatal to scientific progress. Yet in those dark ages were laid many foundations of good things to come.

With the emergence of the modern world out of the chaos of the Middle Age, came the revival of learning and the birth of modern science—from the first a healthy babe, cradled by the ancient and modern literature and the reformed religions; at first walking hand in hand with them, but latterly showing a tendency to use its young vigor to smite down these its old nurses and associates, and to claim the whole field of humanity for itself. It is this young Samson, revelling in his early strength, who presents himself to us now, that we may consider what rights he should enjoy, what duties he should perform.

The right of investigation may now be said to be freely granted to modern science. The denunciations of the impiety of prying into the secrets of nature, and the *jeux d'esprit* once current as to the pursuits of naturalists, are now quoted only to be laughed at, or are confined to such naughty things as vivisection or to the too ostentatious proclamation of our affinity with imagined poor relations like apes and gorillas. Further, the ordinary man of business is well aware that he is indebted to science for most of the conveniences and accommodations that surround him at home, facilitate his movements when abroad, and enable him to communicate with distant friends, as well as for a thousand safeguards that are thrown around his health and his property. He may know little of the facts or principles involved in the transmission of his message across the Atlantic, but he is quite sure that somebody must understand them, and that this somebody, whoever he is, must be a useful and respectable person, and should be encouraged rather than otherwise. Besides, he has a dim notion that there are men still working at problems yet unsolved which may some day minister still farther to safety and comfort; and though he would scarcely feel called upon to contribute to the maintenance of such persons, since after all they may prove to be but dreamers, it would be wrong to hinder them.

Nay, modern society is disposed to go much farther than this. Most of the great civilized countries of the world are now familiar with scientific commissions of one kind or another. We have, for example, National and State geological surveys, which are supposed to be specially intended to develop the mineral resources of the districts which they explore, or perhaps to reflect some glory upon the community which supports them, for its liberal patronage of science. The geological survey, once established, becomes a very general scientific survey, less perhaps for the advantage of economic industries, except indirectly, than had been intended, but greatly for the advancement of pure science.

Occasionally, when some insect or vegetable plague makes its ravages very severely felt, the ridicule which usually attaches to fly-catching and bug-hunting, or the gathering of obscure fungi, gives place to some temporary regard for these occupations, and the entomologist or botanist is subsidized that he may discover the cause of the trouble. The despised man of science thus has his revenge, and he usually takes it. Again, places are often given in our educational institutions to eminent specialists, not because of their ascertained aptitude for teaching, but because of the reputation which they have gained, and which is reflected on the institution with which they may become connected. Thus while education sometimes loses, science gains; but in this way men are often misplaced, and good workers are converted into indifferent professors.

Latterly these imperfect methods have been somewhat decried, and there has been some agitation as to the endowment of scientific research for its own sake—a somewhat difficult matter, for not only has the public to be persuaded to spend its money on what is apparently unprofitable, but the right men have to be found, and care has to be taken that under the influence of generous diet they do not become fat and lazy.

One of the best and safest means of giving such support is undoubtedly that of furnishing facilities for study in great libraries, museums, and laboratories, and in providing means for the publication of results, as is now done in connection with universities and learned societies, and in such great institutions as the Smithsonian and the institutes founded by the liberality

of Mr. Peabody and other benefactors. Another method, also very useful, is that of giving grants for special research, as is now done by the British Government through the Royal Society, and by the British Association. When we consider how little opposition is now made to any kind of scientific research, and how much scientific men are aided by the public, we have perhaps little to complain of in regard to the rights of science. Yet when we reflect on what science has done, how many promising fields of investigation are yet uncultivated, how fruitful even small advances may sometimes be in practical results, it can scarcely be doubted that our niggardly and precarious support of science delays the progress of civilization, and may postpone to future times benefits which we ourselves might enjoy.

Another aspect of this subject must not be overlooked—its educational bearing. Science has a right to a large share in the education of the young. In this it is undoubtedly securing a constantly increasing recognition, but it has not yet attained to its proper position, whether as to quantity or quality. Much that passes for education in science fails because it is not scientific education. The study of text-books, however good—and most of them are very bad ; the cramming of dry elements for examinations—these things are not learning science, and they are themselves, with reference to what we know of mind and its functions, most unscientific. Science has, in short, a right to be taught according to its own proper methods, even although educators should insist on teaching languages and literature as heretofore, in the most unscientific methods possible.

To succeed in this, the teacher must himself know his subject well, and he must have the gift of presenting it acceptably, and the art of presenting it in the most natural order ; and the student must learn, because he hungers and thirsts to know, not because he is driven. Such study of science is valuable, not merely as a means of adding to knowledge. It is one of the best and most practical kinds of training for any future pursuit. So soon as science can be generally taught in this way, it will be the strongest aid and stimulus to other branches of learning, and we shall hear no more of the conflicting claims of science and literature in our educational work.

Some of our most advanced scientific educators hold that in

education science should precede literature, and certainly knowledge and thought necessarily precede expression. It must be borne in mind, however, that all young people begin life with certain natural science studies of their own, and if the educator, instead of crushing all the native inbred tendency to observe and compare, and forcing his pupil to attend to dry abstractions, were first to systematize and render scientific the stores of fact his pupils already have, and then to make these the basis of further progress, learning would become easy and pleasant; but alas! where are the teachers to be found competent to take this first step in rational education? They cannot be found till education in science shall have taken a higher place in our systems of instruction.

At present many difficulties oppose this desirable consummation. Nearly all our educators are still wedded to the abstract scholastic methods of education still in use. Even our science text-books are generally tainted with the same bad leaven. It is difficult to procure apparatus and collections for schools, and still more difficult to secure public appreciation of the work. All scientific educators throughout the world are daily struggling with these disadvantages, and they will in due time be removed. When this shall be, and when science shall have taken its true place as an educator, a new era will have dawned upon the world, in the added force given to intellect, and in the more full and satisfactory solution of all the hard questions which beset society.

Scientific education necessarily presents two aspects: one, that which relates to the training of scientific workers; the other, that which concerns elementary and popular teaching for all. The first is necessary to secure the existence and progress and applications of science, but it must be confined to a comparatively small number. The second represents the diffusion of the benefits of science among the mass of the people; and this also is essential, both to give the public support and countenance which the scientific worker requires, and to leaven society itself with the influence of scientific training. And here I would denounce that old and evil fallacy, that a little science is dangerous. We may, it is true, have too little to be of much service, but every scientific acquisition is intrinsically worth something.

The humblest object-lesson taught in a village school—on a butterfly, a flower, or a crystal—if well and truly taught, is a great and permanent gain to the learners—one that may prove the foundation of vast intellectual wealth in the future. But every thing depends on the little being good of its kind. Where a little only can be taught it should be limited to few things, and these thoroughly and clearly understood. Then will even a little learning manifestly bring the mind into the presence of the Creator's plans, and correspondingly elevate and ennoble it. It is a wonderful thing to observe how the mind of a child craves for insight into the wonders around it, and how it can grasp the comprehension of great laws of the universe, and how it is beyond measure expanded thereby. I fear I may seem too sanguine in this matter, but I have a very deep conviction that few even of our most advanced thinkers have any just conception of the educational value of science, with reference not merely to learning, but to all our political, social, and even religious interests.

The *duties* of science to the world are correlative with its rights. Its cultivators owe it to themselves, their subject, and society that they investigate, apply, and teach; and in considering these duties here, we shall necessarily have to examine from another point of view some portions of the ground already traversed.

Scientific investigation, I need not say, is pursued in our time with marvellous assiduity and success. Besides the few eminent men who are known throughout the world as original discoverers, there are thousands of more obscure workers, unknown, or visible only in very limited circles, who are steadily pursuing their special lines of study, and penetrating farther and farther into the unknown.

The work of scientific research as now pursued is laborious and self-denying. Whether with the telescope, microscope, or spectroscope, with sounding-line and dredge, with hammer or dissecting knife, with crucible, tests and balance, the labor of the scientific worker is long, arduous and wearying, and but for the fascination of such studies it would be matter of astonishment that so many, unaided by public funds, press forward in this career—impelled, it may be, by mere enthusiasm or by desire of fame, or eager to make practical applications.

To some it may seem strange that so much remains to be done, and that the boundaries of nature in every direction have not long ago been reached. Those who think thus have no adequate conception of the practical infinity of the universe. Our knowledge of the atomic constitution of matter, of the motions of its molecules, of their relation to energy in various forms, of the conservation and correlation of forces, of many of the recondite phenomena of life, of the ancient history of the earth, is but of yesterday, and is in all respects so imperfect that all our advances in these and many other directions only seem to open up new vistas of discovery leading to new and perhaps more startling revelations. These new paths of research present new difficulties to be overcome, new positions to be attacked with more powerful and advanced artillery. The cry of science is thus still onward, and its goal of yesterday will ever be its starting-point to-morrow.

One evil attendant on this is the cultivation of specialties to the neglect of general views. Our small army of explorers, spreading out as it advances into the vast regions before it, becomes divided into little bands, and eventually almost every individual seems to be isolated and pursuing a path of his own without concert with his fellows. Hence arises a narrowing of men's minds, a setting up of small objects as of primary importance, a tendency to extreme views, a want of sympathy and harmony. In the old time, when each man could play many parts, it was different. If there was less depth in certain specialties, there was more breadth. Time and growth will restore what of good we have lost in this respect. A good foundation of general education in science will give the younger men now entering on the stage a broader base, and subjects once thought distinct are tending to coalesce. This is markedly the case with the great natural forces of light, heat, and electricity. It occurs also in the domain of organization among animals and plants, broad resemblances being observed where before only differences were discerned. The spectroscope has united optics and chemistry with one another and with astronomy. Geology has welded together in the past history of the earth a great number of the physical sciences. Very recently a text-book has been prepared to teach these relationships under

the name of physiography—a name which may eventually become well known and highly important. It is undoubtedly the duty of science, while pursuing actively the work of research along individual lines, to study practically this consolidation of the sciences.

And here it becomes science to confess with much humility how far it falls short of the full comprehension of nature, and to abstain conscientiously from premature conclusions. The rapid progress of discovery in recent times only makes more plain to us the fact that the extension of our knowledge implies the extension of our ignorance, that everywhere the progress of knowledge leads us to insoluble mysteries. It would be easy to furnish illustrations from every branch of science; but geology and biology are very fertile in them. For example, no fact is better established than that, within times geologically recent, we have had so great changes of climate that at one time the plants of warm temperate latitudes flourished in Spitzbergen and Greenland, and that at another the snows and ice of the Arctic have invaded temperate regions. Contemporaneously with these great vicissitudes of climate, so great changes of the level of sea and land occurred in the northern hemisphere, that our continents were at one time submerged several thousands of feet, and at another were higher and broader than they are at present. Yet geology and astronomy concur in assuring us that the poles of the earth have remained unchanged, and neither has yet given us satisfactory causes for all of the phenomena observed.

Again, we seem to have traced the phenomena of life in their ultimate manifestations to certain complex compounds of the albuminous group. But these are not necessarily endowed with life. They may be either dead or living, and in the latter state they present phenomena of motion and change and growth, which must depend either on some inscrutable rearrangement of their molecules or on some peculiar force which we cannot isolate, or perhaps on both causes. Further, these protoplasmic substances are themselves products of previously existing living beings, and we do not know any way in which they can be produced out of ordinary dead matter. An eminent physiologist, who perhaps as much as any other has labored to evade, if

he could not solve, this problem, has admitted that "the present state of knowledge furnishes us with no link between the living and the not living."

In presence of such mysteries as these, true science must confess that for the present she is baffled. If, instead of this, she should presume to prate of eternal successions of matter and force, or of blind chance, or of evolution of life from that which has no life, or of organic matters immigrating on meteors, she will lower her own standing and reputation with thinking men, though she may impose on the credulous. Her duty here is to investigate further, and if there seems no longer any method of accounting for the phenomena by mere matter and force, to hand over her function to philosophy and religion, and retire from the scene. It is the neglect of this wise reserve that in our time sinks so much of popular science into materialism and atheism, and throws it into antagonism most hurtful to itself and to humanity, with all that is highest and best in our moral and spiritual nature.

But this aspect of the duties of science merits a more searching inquiry, more especially as this may lead us to some fundamental considerations too often overlooked in the eager pursuit of general truths and in the heat of controversy.

In science, properly so called, we are limited to the consideration of matter and force; and in so far science may be said to be materialistic, though its votaries need not on that account be materialists. But, on the other hand, we know nothing certainly of the ultimate nature of matter or force, but study only their phenomena. Again, while experiment teaches us the indestructibility of matter and force, so far as our power is concerned, we know on the one hand that they cannot be self-existent, or have existed from eternity, and on the other hand we find ourselves placed in a universe in which energy is being ceaselessly dissipated into the infinite void, never, in so far as we know, to return, and we can form no conception of the condition of the universe when this dissipation shall be complete. Thus nature seems to contradict our experiments, and to require us to believe in an unseen universe the complement of the seen, and whence all things may be restored. Thus also the legitimate materialism of science not obscurely points to

the immaterial and spiritual, and confesses itself incapable of explaining nature.

This incapacity appears still further if we follow it a little into detail. Matter itself, when viewed from the standpoint of the materialist, fades away like a dream. Its essential properties are said to be extension, mobility, and impenetrability; but the last two really depend on forces acting on it, so that matter becomes merely extension or space in which forces may act; and thus we may be brought to the conclusion of some so-called materialists, who paradoxically affirm that matter is a mere conflict of forces, or, in other words, has no objective existence whatever.

On the other hand, if, like the old materialists of the school of Democritus, we retreat upon atoms, we must accept these, with their various powers and properties, as things ultimate and unaccountable, and we must hold that they possess the potency of all that on this hypothesis has been evolved from them—a doctrine absolutely incomprehensible, especially when we consider that the myriad determinations of atoms into diverse forms and arrangements have to be accounted for as well as their fixed properties.

Again, materialism cannot account for life. To conclude that mere protoplasm or albumen includes all the powers of life, is to take for granted the most important point to be proved, and this in the face of the fact that the properties of dead albumen are not those of living albumen. To say that vitality is no more required in accounting for life than an imaginary principle of "aquosity" to account for the properties of water, is merely playing with words. It might be correct if "albuminosity" was all we had to account for, but not when life has to be explained.

Still less can materialism account for the phenomena of mind. Whether we say that brain secretes thought as the liver bile, or that it evolves thought as a burning body heat, we tie ourselves to the conclusion that mind must be a material thing, to be weighed, measured, and experimented on, and to be transformed back again into matter or force. This we know that it is not; yet thought and will are powers, and are known to us

phenomenally, perhaps more certainly than we know any kind of matter.

We may, however, ask:—if these things are so, how is it that scientific investigation has appeared in so many cases to lead to materialistic atheism. Perhaps this is more in appearance than in reality. Modern science is certainly not to blame for the materialism of antiquity. While the oldest philosophies that we know were theistic, their attempts to explain the phenomena of the universe necessarily led to other conceptions of divinity than those current in the mythologies and popular faith of the time. Hence a newer school, repelled from these old superstitions, went so far as to discard theism itself, and proceeded to construct a chance universe with matter and force. In like manner, some of the atheism of our day may spring from inadequate notions of God in our received theology, and the blood of infidel scientists may be required at the hands of reverend divines who have not rightly presented the truth of God.

The tendency to atheism further arises from the prejudice of all specialists in favor of the causes they have themselves to deal with. It is also frequently produced by unphilosophical ideas of law, as if this included a primary power independent of a legislator behind it. This begets a tendency to suppose that God's personal will is arbitrary, or contrary to law, and that whenever any group of effects can be traced to a law or referred to a natural cause the action of God is thereby eliminated; whereas, if there is a God, what we call law must merely be the method of his acting, in the conditions he has himself established in the existing universe.

Perhaps, however, among more thoughtful men, the seeming contradiction between the imperfection of nature and what might be expected from an infinite mind has been the most potent cause of an atheistic tendency.

We are familiar with the sombre view of nature taken by our great English philosopher, John Stuart Mill—his belief in design in the universe, yet his doubt whether the designer could be omnipotent, or, if omnipotent, could have desired the happiness of his creatures. Yet we may not have considered the profound natural truths that lie beneath the plane of Mill's

vision, just as geological strata, with their wonderful revelations, lie beneath the soil. What is creation? It is not the addition of any new power to an Infinite Being. It is merely a voluntary local limitation of his power. Hence what we call natural law must be merely a local and temporary fact with infinite exceptions, and in many important respects the created must be the converse of its creator. If he is infinite, it is finite. If he is perfect and unchanging, it is imperfect and mutable. If he is eternal, it is transitory. For these reasons the mutations, destructions, sufferings if you will, which exist and always have existed in the universe, are not reflections of the nature of the Creator, but mere foils against which his infinite glory becomes discernible. Nature cannot be a reflection of the character of its maker except in that broken way in which rippling water reflects the sun. I do not here refer to the moral evils introduced by man, but to the necessary contrariety between material nature and an immaterial creator. We can see also that in this region lie the roots of the pessimism and dualism of certain ancient religious and philosophical systems, which, however crude, were more far-reaching than some of the philosophies of to-day, because less encumbered with scientific appliances and superfluities. We may also see in this an explanation of the growing acceptance by a certain class of thinkers of the philosophical system of Spinoza, which, whatever its defects, adheres to the old Hebrew revelation in maintaining the unity and uniformity of nature, in spite of its apparent self-contradictions, and of the want of connection of matter with mind, and of the apparent want of harmony of both with the infinite Creator.

It was also Mill, I believe, who suggested the possibility that there might be some place in the universe where two and two are equal to five. However absurd this may appear, it is nevertheless true that what we call invariable natural law must be a limited thing, and that what we now call miraculous, supernatural or spiritual, must be the action of the infinite and eternal rule, to which all our natural laws must be temporary and local exceptions, for "the things that are seen are temporal; the things that are unseen are eternal." This is a conclusion independent of any theology—a conclusion forced upon us by the conditions of thought and the phenomena of nature; a

conclusion which should teach us humility, and point out to us the limit where it is said to the science of nature, "Hitherto shalt thou come, and no farther."

Yet must the seen and the unseen be parts of one system. Nature is to our limited view like a landscape seen through the window of a railway carriage, in which the nearer objects seem flying past almost too rapidly to be discerned, while the distant hills or little patch of cloud-dotted sky seem permanent. Yet are they all parts of one fixed landscape. The parallax arising from our peculiar standpoint makes the difference.

I would not wish to be understood as depreciating in any way the adaptations of natural objects, or the wonderful contrivance, order, and beauty everywhere apparent in nature. These it must ever be at once the duty and the pleasure of the true naturalist to maintain. I remember that in younger days, before I had decided whether biological or geological studies had the greater attractions, I had occasion to dissect a ruby-throated humming-bird; and I recall as vividly as of a thing of yesterday the impression which that marvellous structure made on me. To see all the parts of the highest type, in a mechanical point of view, of the vertebrate animal, condensed into a little creature whose solid body is not so large as the last joint of one's little finger, and to think of the power, the swiftness, the grace, the varied instincts and intelligence and feeling manifested in that tiny frame—all this was sufficient to have made one worship the beautiful little fairy, as some of our southern aborigines actually did, were it not subject to accident, to death and to decay, and were it not an obvious manifestation of a higher power. Whoever has rightly appreciated the structures and powers of a humming-bird has been introduced to a miracle of design; and, as Gould and the Duke of Argyll have well shown, the multiplication of that miracle in hundreds of dissimilar species by no means lessens its significance. Only a mental organization diseased can see the universe as a chaos or a failure; but we must learn to know that, after all, it is but a faint shadow of the invisible glory, and it would be an equally fatal mistake to exalt it into a God, or because of its necessary imperfection to fail to perceive its divine original.

Another duty of science is practical application; and here

also modern science has nobly done its duty, as the vast development of scientific arts ministering to the safety and comfort of life amply testifies. I do not propose here to travel again the beaten path of laudation of the triumphs of science ; but some recent inventions point this truth so well, and illustrate the rapidity of progress in so striking a manner, that they may well invite our attention. It is but yesterday since the invention of the telephone startled us with the possession of a new power, vast in the promise of utility which it holds forth. Still more recently the invention of the phonograph has given us the power of perpetuating fleeting sound, and of handing down to future times or sending to distant places the very tones and notes of orators and musicians—of sealing up spoken words in silence for an indefinite time, and then at will giving to them all their original expression. Such a power we could scarcely in our wildest imaginations have dreamed of, and might have placed the anticipation of it in the same category with the story of Baron Munchausen's frozen horn. As if this were not enough, still another instrument, the microphone, has been brought out, which does for sound what the microscope does for light, rendering the march of a fly audible as the tramp of a charger, and opening an entirely new path of discovery with reference to sounds hitherto inaudible, and inappreciable vibrations of molecules. Yet these are simple inventions—simple, at least, after science has shown the way to them. Viewed in this aspect, they startle us with the thought how different our whole civilization might have been had the phonograph preceded the alphabet ; and we can see that even yet the literature which addresses itself to the eye may be largely superseded in the future by that which can be received by the ear. Perhaps also they may serve to impress us with the vastness of the unknown possibilities which, undreamt of as yet, may still be very nearly within reach of the scientific workers who are struggling to grasp them. What efforts, for example, are now being made to predict storms and changes of weather, and to reduce the fury of the tempest to the compass of the laws of God understood by man ; and what remarkable researches and discussions are in progress respecting the germs of these minute organisms which are the leaven of diseases and of decay ! We may be sure these

efforts will be successful. Science will yet chain and tame the demons of the storm, and shut up again in Pandora's box those germs of evil, which that old fable represents in their minuteness and their hidden energy.

A curious aspect of this subject is presented in a series of papers by Mr. Norman Lockyer, now appearing in "Nature," and treating of "Physical Science for Artists." It would seem that in many respects our brethren of the pictorial art have been neglecting to avail themselves of the progress of knowledge. Their sins in representing the sun and moon in impossible quarters of the heavens and impossible phases are well known, but Lockyer goes on to notice some less known eccentricities. The size of the sun or moon as it appears in a picture is a measurable quantity—about half a degree of the heavens. Hence the size of the solar disc in a drawing or painting may give a measure for other distant objects. Tested in this way, the landscapes at a certain recent exhibition of paintings (we need not mention where) are said to have given the following results as to the height of hills. Some mountains, according to the painters, attain to the amazing altitude of 105 miles. About an average height is forty-four miles, and hills so small as to be less than thirteen miles in height are rare. This is a trifling illustration of a fact more gravely evidenced in other matters, that science has not yet attained to sufficient diffusion to bear its fruits for the benefit of all men. None of us probably have any adequate conception of the extent to which the general application to the ordinary needs of life, of science, even as now known, would increase the happiness of mankind and mitigate the waste and loss of life and health which desolate the world, even in its most advanced and prosperous communities.

Permit me here to refer for a moment to one department of scientific work still in its infancy. I mean the science of utilizing science. Of what we know and have actually accomplished how little benefit is yet realized compared with what might be? How little regard do men pay to the physical laws already known? How little benefit do they derive from the powers we already possess? What, for instance, might be the condition of the world if all that is known of the laws of health and disease, of the means of immunity from fires, from explosions, from acci-

dents by sea and land, could be reduced to practice—if all the vast stores of material and power at our command could be equitably and usefully employed for the true benefit of all? To this end moral training and scientific culture of the whole mass of society to an extent of which we have no immediate prospect will certainly be required. We sometimes wonder at the small amount of actual command of nature acquired by the civilizations of antiquity. Our successors will wonder in like manner, and perhaps with more reason, at the little good which we derived from the vast amount of natural power at our disposal, and will probably discuss the question whether our failures were more due to moral or to mental incapacity. To them we will appear like misers gloating over heaps of gold while we are perishing of want. Surely it is one of the highest duties of science to set itself to study and, if possible, to remedy this great defect of our modern civilization, however dangerous it may be to assail a problem so mixed with social, political, and religious prejudices.

The teaching of science we have already glanced at from the side of right. Viewed from the side of duty it presents itself in a still more important aspect, since here the man of science ceases to be an isolated worker, and comes forth to make permanent impressions on the minds of his fellow-men. This is the case whether science education be undertaken as a profound and thorough professional work, or whether it be followed merely in the manner of the popular lecturer or writer.

I would here repeat, though without dwelling upon it, that the first requisite of the science teacher is that he teach in a scientific manner—that is, so far as the arrangements of educational institutions will permit. There is a constant tendency to allow science teaching to degenerate into a mere cram of text-book facts. When the teaching is carried on without proper appliances, and by teachers themselves not specialists, this is inevitable; but even where these circumstances are favorable, the teacher will find that his pupils have already, in previous stages of education, been so thoroughly trained in the system of book-cram, that it is very difficult to induce them to observe or think for themselves. I have been surprised to find that classes of young men will rather commit to memory a dry

text-book or imperfect lecture notes, than open their eyes to see for themselves and exercise their minds in perception and comparison, so thoroughly has the natural habit of observation been crushed by previous vicious training. This is one of the first evils the educator has to counteract, the next is to eradicate the habit of receiving statements on authority, and to stimulate the mind to the contrary habit of "proving all things," a scientific as well as religious duty.

As for the science teacher himself, he must be a true learner and enthusiast in his subject. He must teach what he practically knows, and this in a practical manner, so that the learner shall know it in the same way. He must, in the order of his teaching, follow nature, and not himself merely; and he must induce his pupils to observe, reason, and judge for themselves on every point, and to receive nothing either as fact or law that they cannot explain and defend. A very little of such teaching however elementary or however popular, may be the sowing of seed that will produce abundant harvests. It is to be observed also that in this way the teaching of science must react favorably on all other kinds of teaching. It has already done so, and will do so more markedly in the time to come. When this beneficent revolution shall be complete, we may hope to see students striving for excellence, because the appetite for study has been awakened in them, because they love learning for its own sake; not turning the weary treadmill of cram for hated examinations, or learning only because it "pays" in college distinctions or in some prize or medal or opening to professional life. This millennium of education, I believe, is to be introduced only by the extension and development of education in science.

One other point before leaving this subject. Every scientific man knows how painful are the travestied references to scientific facts which we find constantly paraded by way of illustration or argument by popular writers, lecturers, and preachers. But we must not suppose that the inaccurate and often absurd character of these references arises altogether from lack of information. It is often due rather to an entire want of habits of scientific thought, rendering the recipient of much miscellaneous knowledge incapable of reducing it to order, or of comprehending its true import. Here, again, accurate scientific educa-

tion is the remedy for the evil, and this perhaps not so much in the direction of the communication of knowledge of facts as in the training in methods of observation and thought.

At the present time one of the greatest temptations of the scientific teacher is that of diverging into the sphere of speculation and hypothesis, and of being induced to present such uncertain utterances as if ascertained truths of science. Our age is full of appetite for the sensational. It has exaggerated notions of the powers of science, and nothing pleases it so much as some grand and pretentious generalization, however little supported by fact. In my own department of palæontology, theories of the spontaneous origin of living beings from dead matter and of the production of species by natural selection, phylogenies or imaginary genealogies based on conjecture, doctrines as to the antiquity and brute origin of man, are examples of speculations often vaunted as actual discoveries, though at variance with the testimony of facts as at present known. Such speculations have their value, as representing the longing of the human mind after the ultimate reasons of things, and as pointing to possible lines of discovery, but the inducement to parade them as facts or known laws arises too often from that pride of supposed special insight which is so dear to the half-educated mind, and which induced the astronomers of old to profess astrology, and the alchemists to search for the philosopher's stone. They are very well when kept in their proper place as uncertain topics of discussion; but when introduced in text-books and popular publications, they constitute treason against the majesty of truth, and entitle their promulgators to nothing less than banishment from the fair fields of science.

It is not to be disguised that much of our current scientific literature sins in this respect; and this the more dangerously, since it mixes up the most interesting and suggestive facts with the wildest fancies. The relations of colored and odoriferous flowers to the haustellate insects, and the reciprocal benefits that flow to flowers in regard to cross-fertilization and the prevention of undue sports and varieties, and to insects in the supply of food, and to all nature in the beauty and variety communicated to it, are subjects well deserving the investigation of naturalists in their minutest details. But when the natural-

ist proceeds to maintain that this is the sole object of colored flowers and honey-loving insects, that all color is for this express purpose, that colored flowers cannot fertilize themselves, that in the past ages of the world flowers and insects spontaneously produced each other, he at once degrades his subject to a low materialistic and even repulsive position, and offends against natural truth. When Darwin remarks on the remarkable aversion displayed by monkeys to serpents, he states a curious fact; but when a disciple proceeds to reason that this must be the cause of the aversion to serpents displayed by some human beings, and of the introduction of the serpent into the story of the fall of man, he descends to the ridiculous. His folly has not even the sublimity which it might have assumed had he insisted that, inasmuch as men and monkeys were both at one time marsupials, they may have inherited this aversion from the terror of mesozoic marsupials at sight of the dinosaurian monsters which preyed on them. The revelations of Marsh and Cope with reference to the wonderful and abounding life of the early tertiary periods in America, and the relations of these old animals to those of the modern era, are among the most striking of our time with reference to the plan of creation; but they degenerate into what common-sense designates as a monohippic or one-horse philosophy, when, by arbitrarily selecting facts, ignoring the possibility of future discoveries, and assuming sequence in time as equivalent to causation, they are made to demonstrate the descent of the modern horse from eocene ancestors generically different. Even supposing that there is some faint possibility that the horse may have been derived from previous species of equine animals, and what is even (if that can be) less likely, that we have some means of guessing the direct line of descent, such speculations should never be placed in company with ascertained scientific results.

But it is not my purpose now to dwell on this hackneyed theme. The materialistic evolutionary philosophy of the time has been pushed to the extreme. It was from the first unscientific and is now on the wane, and it remains to gather up the truths which have been gained in its pursuit, and which may aid in constructing other like or unlike theories, or perhaps in con-

tributing to the solid advance of science. What I wish to insist on here is that science is not to be held responsible for speculations of this kind, which rather belong to the domain of philosophy ; and that these should not be taught as science, but that the science teacher must keep within the limits of fact and safe induction, unless he desires to be branded as a charlatan and as a professor of science falsely so called.

Science teaching has great and important duties to discharge with reference to other interests and pursuits, and with reference to the higher sentiments and aspirations of humanity. Our complex humanity cannot be all devoted to one pursuit, and scientific specialists who become mere slaves of their particular study, and who despise the feelings and pursuits of other men, are little fitted to be teachers.

Natural science is closely connected with our æsthetic perceptions, which are of divine origin, however much they may become distorted and abused. That we know the structure of a flower and can give names to its parts, is surely no reason why we should take less pleasure in its form, its colors, or its perfume. Rather it should greatly enhance our appreciation of these wonders, so attractive even to a child. That we know the structure and age of a mountain chain, or understand something of the motion of glaciers, should surely not harden our hearts against the sublimity of Alpine scenery. Rather it should fill us with new awe, in view of the time and the forces involved in the foundation of the everlasting hills. It is not too much to say that no teacher of science whose own imagination is not fired with a sense of the beauty in nature, and who fails to avail himself of the natural feeling for beauty, can be in the highest degree successful. Nay further, in addition to taking advantage of what all can see and appreciate, he must be continually bringing into view new beauties not seen by the unlearned. Such marvellous and artistic structures as the microscope discloses, in the minute parts of plants and insects and sea-urchins, in the crusts of polycystins, foraminifers, and diatoms, and in the gills of certain mollusks, are admirably fitted to enlist the interest of learners, and to enlarge their appreciation of nature. At a time when so much that is essentially monstrous is admired as art, such culture it is especially the

duty of science to give ; and it requires but a limited knowledge of human nature to perceive that the mind which has lost its relish for nature's beauties, and delights itself in grotesque or hideous productions of art, is thereby degraded even morally and intellectually.

Again, the instructor in science must not teach atheistically, or even be content with that provisional materialism which one of the great popular teachers of our time commends as expedient. Nothing can be gained by a teaching essentially false or imperfect, and which destroys that sympathy of the human soul with nature which gives to its study the greatest attractions. If, as we have already seen, mere materialism cannot explain even matter, still less life and mind, the teacher who has nothing beyond this in his philosophy is sure in the last resort to be ignominiously driven back on the absurdities of eternal succession and of order and unity resulting from chance. If he is content to postpone the difficulty by resting his faith on any of the popular forms of evolution, he is in no better position than the Hindu who supports the earth on an elephant and the elephant on a tortoise ; and he scarcely improves his position by placing the tortoise on an ascidian, the ascidian on a protozoon, the protozoon on a particle of protoplasm, and the particle of protoplasm on an atom. The weakness of such a system is certain to be detected by the common-sense of his pupils, unless indeed he can succeed in reducing them to the same state of imbecility in this matter with himself, which would be a pitiful outcome of science.

Nor can the science teacher logically stop short of the fullest admission of design in nature, with all its consequences. In our time the doctrine of teleology and final causes is much scoffed at by some able scientific specialists, and many unthinking persons take up the cry and profess in this matter to be wiser than the ancients. Yet even these persons, while protesting against the idea of purpose, cannot speak of nature without reference to ideas of use, fitness, and adaptation, which, on any other theory than that of blank materialistic atheism, involve design in the fullest sense. It is surely far from the duty of science to vitiate its teachings with the paradoxes of the "dysteleologists." It may indeed well be asked what object, either for science or

humanity, can be gained by an attitude of cold negation and sour misanthropy on the part of the man of science, or why he should oppose himself to even the sentimental love of the human mind for nature. The only result can be the rendering of science itself unpalatable, and causing it to be rejected as mental food, or, if received, to fail of any healthy digestion.

This leads finally to the statement that it is the duty of science to work and to teach in harmony with the religious sentiments of mankind. When it sets itself in opposition to religion, its scepticism carries with it the double reproach of doing evil and of going out of its own way to do evil. I take religion here in no narrow sense. Let every man construct the details of his creed for himself. I take it in the broadest sense, as the development of that one idea in which Christian, Mohammedan, and heathen agree—the belief in immortality. This is the one universal religious doctrine which spiritually dignifies humanity and elevates it above the brutes. On the one hand it leads the human mind directly to God, on the other it is itself a necessary outcome of theism. Nature cannot have been without a maker, and if there is a God, all who have ever lived, to use the words of Jesus, "live unto Him." In that conservation of spiritual forces which is surely as real as that of the grosser energy which works the material world, no living soul can ever die unto God. Dead they may be to us, as the sunshine of last summer is dead; but living still as surely as that lost sunshine still vibrates somewhere and for some end in the universe of God. Science itself may more or less distinctly reason out this conclusion, but independently of science it is forever fixed in the instincts of humanity, and it is madness to set it at naught.

But let us hope that such tendencies to evil companionship on the part of science as appear here and there are but evanescent, and believe that even now they are vastly outweighed by her substantial services to humanity. Let us look on the god-like form of science, as the bold and courageous investigator bringing her hard-earned trophies from every field of labor and adventure; let us look on her as the tender and loving applier of all her treasures to relieve the wants and promote the happiness of mankind; let us look on her as the wise and diligent

instructress, training the minds of men into harmony with nature and with God. So shall we recognize her divine lineaments. So shall we claim for her her rights at the hand of society, and shall rejoice in her fulfilment of her great mission in the world—a mission of which we have seen but the small beginnings, and which must go on blessing humanity, till, in the upward progress of our race and the development of the plans of God, science and religion, earth and heaven, the material and the spiritual, time and eternity, become one in the light of the glory that excelleth, for they are really all one in Him who is all in all.

J. W. DAWSON.

Natural Science in the Past and the Future

Dedicated to Contemporary Clergymen, with the wish that their mind may be as humane as that of their predecessors.

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