GIFFORD LECTURES

LECTURE I

Freer introduction of scientific subjects and Christian doctrines—Illustrations of the immense distances of the heavenly bodies—Their visibility implies a connection of some kind—Corpuscular and undulatory theories of light—Triumph of the latter, and evidence of the existence of the luminiferous ether—Which, nevertheless, is not recognisable by our senses—Its connection with electricity—Possibly with gravitation—Unexpected constitution of ether indicated by the phenomena of polarisation—The history of the theory of light warns us against a summary rejection of what seems inexplicable by natural causes.

In commencing my second course of Gifford Lectures, I feel that I ought, in the first instance, to make my apologies to the University for the delay which has occurred, as they ought properly to have been given in my second year of office. I have next to express my thanks to the Senatus of the University for having accepted a proposal I made when it was too late in the past academical year to lecture at a time suited to the wants of the University, that

I should be allowed to deliver them during the present year instead. I come before you therefore to-day, not as actual, but as *ex*-Gifford Lecturer. I find that the arrangements which the University authorities had made with my successor are of such a nature that I trust no serious inconvenience will arise from the change, and I do not think there is anything in it that can be distasteful to or uncourteous towards the present holder of the office.

At the conclusion of my former course of Gifford Lectures, I expressed the intention, in case it should fall to me to deliver another course, of dealing more freely with subjects to which I had myself paid more special attention,—I mean scientific subjects in so far as they might appear to aid us in the theme to which the attention of the Lecturer is directed by the will of the Founder.[1] I said also that I should allow myself greater liberty in referring to distinctively Christian doctrines, not with the purpose of entering on the subject of Christian evidences, which would be quite foreign to the foundation, still less of engaging in polemical theology, which is expressly prohibited, but of pointing out what it is that is really involved, and that as a rule runs throughout the belief of Christendom. And surely if

[1] An extract from Lord Gifford's Will, showing his object in founding the lectureships, and the qualifications and duties of the lecturers, is printed at the end of the volume.

Christianity does not destroy, but supplement and fulfil, those seekings after God, those endeavours to methodise the principles of right conduct, which may be made by the exercise of the powers with which man is endowed, it cannot be reasonable to exclude all reference to Christian teaching, nor can I imagine that Lord Gifford intended that it should be thus excluded.

I have reason to think that the expression of an intention to bring before you rather matters that had occupied my attention than those which were new to me, and which I could only offer you at second hand, was received with favour; and in part fulfilment of my expressed intention I propose to-day to direct your attention to some questions connected with our present scientific knowledge.

It would not, however, be lawful for me, as Gifford Lecturer, to deliver to you a scientific lecture merely as such, and on account of the scientific interest of the subject that may be treated. But if we look on the framing of the material universe, the replenishing of the earth with living things, the formation of man with all his intellectual powers, his endowment with the sense of right and wrong, and generally with moral faculties—if, I say, we look on these as the work of a supreme Author of nature, then we may expect to find some general rules, or at least some analogies, running through even dissimilar portions

of His work. It is conceivable that, even in the study of inanimate nature, we may get hints as to God's moral government of His rational creatures. But to perceive such hints it is not necessary to go through the various branches of Natural Science. Nothing more than hints of the most general kind as regards moral science need be expected from a subject so different as natural science; and such, if they are attainable, we might expect to find rather in what is common to different branches of natural science than in what is distinctive of some one branch.

By way of introduction to the subject which I propose to bring before you to-day, I wish to say a few words to help to give some idea which we can actually realise of the distances of the heavenly bodies. Statements regarding these distances are indeed to be found in every elementary text-book dealing with such subjects; but it is one thing to accept such statements as true, on the authority of those whom we believe to be competent to make such statements on grounds which we cannot in the least comprehend, and another to be able to form some idea of the sort of evidence on which the statements depend.

Now it requires no stretch of imagination to conceive that we should be able to make out the general form and the dimensions of the earth on

which we live. We travel long distances along it; we can sail round it. To describe the refined methods by which its dimensions are most accurately ascertained, would lead me altogether too far from my subject. Suffice it to say, that it is thoroughly well proved to be very nearly spherical, with a radius of about 4000 miles.

The heavenly bodies are not, however, accessible to us. How then can we imagine their distances from us to be measured? To form a conception of this, suppose that we wished to ascertain the distance of some inaccessible object on the earth's surface, such as a rock a long way out at sea, we ourselves being confined to a small island. Let us take two stations on the island, some way apart, and so chosen that they are visible from each other, and the rock visible from both, and also that the distance between them can be measured, suppose by a chain. At each station we can observe the angle between the directions of the other station and of the rock, and thus in the triangle formed by the three objects, as we have measured the base and the angles at the base, we can calculate the sides, which are the distances of the rock from the two stations.

If our supposed island were of very small dimensions, and the rock a very long way off, our triangle would be so slender that, unless the two observed angles were measured with very great precision, our

result could claim no great accuracy, though even in that case we *should* be able to affirm that the distance of the rock was *at least* as great as so and so.

Now we may endeavour by a somewhat similar operation to determine the distance of the heavenly bodies. In this case the earth on which we live takes the place of our small island, and by choosing two stations widely separated on the earth's surface we may procure a base of some thousands of miles. It is true that in this case the stations are not visible from each other; but as they are on known points on the terrestrial globe, the dimensions of which we know, it can be imagined that by suitable calculations, combined with observations of the heavenly body, which takes the place of the rock out at sea in our illustration, it might be possible to arrive at a definite result as to the distance of the body in question.

By methods of which the preceding illustration may serve to give a general idea, the distance has been ascertained of our nearest neighbour, the moon, which proves to be about a quarter of a million of miles. Already we have arrived at a distance which we hardly realise without reference to something with which we are more familiar to aid our conceptions. We are familiar with railway trains, and it may help us to reflect that it would take an express

train, travelling without stopping night or day, eight months or so, to get over the distance from the earth to the moon.

If we attempt to ascertain the distance of the sun by the direct application of similar methods, we find it to be so great as to prevent us from obtaining trustworthy measurements of it. But by indirect methods, still depending on the dimensions of the earth for a base line, it has been ascertained that the distance of the sun is about 92,000,000 miles—about 400 times the distance of the moon.

The distances of the stars are so enormous, that no methods founded on the direct employment of the distance between two points on the earth's surface as a base line would lead to any positive result. But in the course of a year the earth revolves round the sun in an orbit which is nearly circular, with a radius of 92,000,000 miles. It is conceivable that though we failed to observe any appreciable displacement in the direction of a star according as it was viewed from one side or the other of the earth on which we live, yet if we were to observe it from two points separated by such an enormous distance as the diameter of the earth's orbit, some appreciable change in the star's direction might be perceptible, which might enable us to ascertain its distance from the sun, the centre of our system. In point of fact, such changes of direction have been ascertained to

exist in the case of some of the stars, but so excessively minute that, even in the case of α Centauri, which so far as we know at present is our nearest neighbour among the fixed stars, the concluded distance of the star is so great that if the earth's orbit round the sun could be seen from the star, it would not appear as large as a threepenny piece seen at the distance of a mile. And we have every reason to believe that there are multitudes of stars vastly more distant than that.

In spite of these almost inconceivably great distances, the fact that we do see the stars shows that there must be a connection of some kind between us and them. It does not at once show that light is of the nature of a messenger conveying to us information respecting the star; for the word "messenger" carries with it the idea of something travelling; and it is conceivable that the influence of the stars on us, which results in our seeing them, might have nothing to do with progress from place to place, but might be instantaneous. Nevertheless, long before the distance of any of the stars had been even approximately measured, two perfectly independent astronomical phenomena had revealed to us the finiteness of the velocity of light, and had enabled us to determine it. I allude, of course, to an observed inequality, as it is called, or periodic variation, in the observed times of occurrence of the

eclipses of Jupiter's satellites, and to a remarkable apparent annual displacement of the stars called aberration. These two phenomena fall so completely into their places, and the values of the velocity of light determined in two such utterly different ways agree so well together, that no doubt can remain that the professed explanation which refers them to the finite velocity of light is indeed the true explanation. And within the last half-century the velocity of light, notwithstanding its enormous magnitude, has been actually determined experimentally in terms of measured distances in the neighbourhood of the station of observation, or even in the room in which the experiment was made, and a value obtained for the velocity which closely agrees with those given by the two celestial phenomena. In these ways we now know that the velocity of light is a little over 186,000 miles per second. Vast as this rate is, corresponding to the passage over a distance exceeding seven times the circumference of the earth in one second, it yet would take about three and a half years for light to travel from α Centauri to us; and this reference to the velocity of light aids us in conceiving the enormous distance of even the nearest of the stars.

Now there are two, and as far as I can see, only two, possible ways in which we can conceive of the transmission of such a message: either we must

have something darted forth with this enormous velocity from the body from which the light comes, or a certain change of condition must be propagated in a medium already existing, if not in infinite space, at least as far as the remotest visible star. These two radically different conceptions lie at the base of the two rival theories of light which, for a long time, divided the allegiance of men of science—namely, the corpuscular theory, or theory of emission, and the theory of undulation. The former, supported as it was by the great name of Newton, was for a long time that most in vogue. But subsequent researches have brought to light such an overwhelming amount of evidence in favour of the theory of undulations, that there cannot be a moment's hesitation which alternative we must adopt as to the nature of light; and at the present day the statement that light consists in undulations may be regarded as one of the certainly ascertained results of scientific inquiry.

The undulatory theory demands of necessity the existence of some sort of *medium*, as it is called, extending at least to the remotest star, and existing likewise within such bodies as glass, water, etc. It would take me much too far from my subject to enter into the arguments, on the strength of which we conclude that this medium (to which the name of *luminiferous ether* has been given) exists within ponderable bodies, as well as in free space.