approved Neo-Lamarckian manner the moulding of limbs and the skeleton generally as the result of the forces to which they are exposed during the life of the individual. In the explanation of the remarkable lengthening of the fore-part of the giraffe we meet with a suggestion which is, I believe, new in the history of Lamarckian speculation. In stretching for food it is contended that the animal "must have constantly raised itself off its fore-feet, and as it dropped must have received a shock that made itself felt from the hoofs through the legs and vertical neck to the head. In the hind-legs the shock would not be felt. . . . The principle of increased growth in the direction of the shock resulting from superabundant repair of the momentary compression, explains how the giraffe acquired the phenomenal length of the bones of its fore-leg and neck; and the absence of the shock in the hind-quarters shows why they remained undeveloped and absurdly disproportionate to the rest of the body." (pp. 164-165.) It is unnecessary to take the trouble to refute the details of the various suggestions brought forward by the upholders of the Lamarckian hypothesis: they refute each other. One of them explains a lengthened neck as the result of extension, another as the result of compression; while neither give any approach to a proof that such an effect is likely to result from the antagonistic forces which they respectively invoke. E. B. P.

CELESTIAL PHOTOGRAPHS.

A Selection of Photographs of Stars, Star Clusters and Nebulæ, together with information concerning the Instruments and the Methods employed in the Pursuit of Celestial Photography. By Isaac Roberts, D.Sc., F.R.S., &c. (London: The Universal Press, 1894.)

THIS handsome collection of celestial photographs is a remarkable example of what can be done single-handed in a new line of research. Taking up celestial photography more than ten years ago, Dr. Roberts has devoted himself entirely to it, and has been rewarded with an amount of success that must be to him a source of intense satisfaction.

This success, however, has not been obtained by merely exposing plates in the telescope and watching the images come out in the developing dish. The work that Dr. Roberts set himself to do was planned at the outset in a thorough manner, and has been carried out apparently without regard to either labour or expense; even to the extent of the removal of the observatory near Liverpool, to a better position, selected after a most exhaustive discussion of weather conditions in the south of England.

In the introduction of his book Dr. Roberts tells us that a reflector of twenty inches aperture was the instrument decided upon, in consultation with Sir Howard Grubb, as the most likely to give the best results. An instrument of this size, arranged for exposing the plate without the use of a plane or prism, was made and mounted by Sir Howard Grubb in 1885. With this instrument all the celestial photographs have been taken.

The first arrangements do not appear to have been

quite satisfactory, so that the telescope had in great part to be reconstructed; but even then the star images were found, on trial, to be elongated, though this defect seems to have been remedied later on, if one may judge by the remarkable absence of any deformation of image in some of the very long exposure photographs.

The question of the utility of the photographic chart is discussed, and the fact mentioned that Dr. Roberts had already, in 1885, begun a photographic chart of the northern heavens, and made some progress, when the International Congress for the Photographic Chart of the Heavens took up this work. The use of the paper copies of celestial photographs might, it is suggested, be (1) the detection of changes in the structure of nebulæ; (2) the detection, on a large scale, of movements amongst the stars; (3) determinations of variations in stellar magnitudes; (4) relative distribution of stars in space; (5) detection of new stars and disappearance of others.

In cases, however, where measurements to a second of arc are required to be made, then the original negatives must be used for the purpose; and in this we quite agree with Dr. Roberts. It would have been well worth while to picture, in this connection, the instance given by Dr. Roberts of his comparison of a chart of the heavens, made in 1863 by D'Arrest, showing 212 stars, with a photograph of the same region taken in 1890, which showed that considerable changes had taken place among the stars in this small area of the sky (comprised within one degree of declination and half a degree of right ascension) during the interval of twenty-six years between the epochs of the charts.

The relative advantages of refractors and reflectors as photo-instruments, and the requirements and adjustments of a reflector for celestial photography are discussed; and the ideal instrument for photographing the sun, moon, and planets is given as a refractor of six or eight inches aperture and very great focal length; but for the delineation of faint stars and faint nebulosity, Dr. Roberts gives a preference to the silver-on-glass reflector, and he would choose an instrument of twenty-seven inches clear aperture and eleven feet three inches focal length, the mirror being figured, and every part of the mechanism made in the most perfect manner possible, and with a guiding telescope with an objective ten inches in aperture. To anyone contemplating the erection of an instrument for celestial photography, these hints—the results of many years' experience—should be of great value.

The other chapters, on the collimation of the mirror, the essentials of a photo-telescope, method of testing the stability of a photo-instrument, and photographic plates, their exposures and developments, will be read with great interest by all photo-astronomers.

The chapter on the collimation of the mirror gives an account of the method employed to check the guiding telescope, and is perhaps the only point on which something might be said in the way of criticism of Dr. Roberts' method. It is difficult to see why the method described should not be varied so as to be always available, and so dispense with the guiding telescope; a matter of no slight importance in the case of such an instrument as Dr. Roberts has suggested, the ten-inch objective of which would cost as much or more than the mirror. We

believe Sir Howard Grubb has already suggested some such method.

We should have very much liked further information about the instrument, the supports of the mirror and the plate-holder, and other details, but these are perhaps rather in the province of the telescope-maker than the photo-astronomer. A photograph of the double telescope, however, gives a very good idea of the general arrangements, and there is also a photograph of the observatory.

Of the forty-nine celestial objects reproduced on paper, four are star charts, twenty-two are clusters of stars, and twenty-three are nebulae. The earlier and most important photographs in this collection have already been published in various ways, and many of the others exhibited at the meetings of the Royal Astronomical Society; for Dr. Roberts, with proper scientific spirit, has always been ready to place any of them at the disposal of astronomers; but they lose nothing of their great interest by being seen in the collected form.

Had Dr. Roberts' work been only to produce the first photograph, that of the great nebula in Andromeda, and had that been the only result of all his labour, he would have been amply repaid, for it is certainly not too much to say that, in this picture, photography has done more to justify its use by the astronomer than in any other case; and one can feel that the hopes that were formed by Rutherford and others in the early days of photography, and which lay dormant for so many years, have now been realised. The perfection of delineation enables the true character of this marvellous object, which remained hidden from the closest scrutiny of such a careful and competent investigator as G. P. Bond, to be at once seen and appreciated. It is difficult to imagine that such an enormous object as the Andromeda nebula must be, is not very near to us; perhaps it may be found to be the nearest celestial object of all beyond the Solar System. It is one that offers the best chance of the detection of parallax, as it seems to be projected on a crowd of stars, and there are well-defined points that might be taken as fiducial points for measurement. Apart from the great promise this nebula thus seems to give of determining parallax, there is a fair presumption that in course of time the rotation of the outer portion may perhaps be detected by observation of the positions of the two outer detached portions in relation to the neighbouring stars.

The photographs are arranged in order of right ascension, each has its position given, and many have marked fiducial stars whose position is given for 1900. The scale of enlargement is also given, so that with the help of a table of corrections of errors due to the slight alterations in scale in enlarging or printing, any point on the photograph can be determined with an accuracy sufficient at least for purposes of identification.

For some purposes, no doubt, it will be absolutely essential to have recourse to the original negatives, but, as Dr. Roberts has pointed out, there are many purposes for which these paper copies are available. In addition to the full date of each object, which is admirably done, there are various useful references to previous observations. The accuracy with which the telescope is kept

pointed during a long exposure is seen by a glance at the shape of the brighter star images, as a shift, if not at once corrected, produces deformation. In nearly every photograph the stars are round, in some they seem absolutely so, which shows the perfection of the instrumental arrangements of Sir Howard Grubb, and the care with which the exposures have been made. Some of the star photographs—as, for instance, plate 43—show a perfection of image and an absence of distortion over a large field that is very satisfactory. A comparison with a plate of the same region taken by an International Chart refractor would be interesting.

In looking at the examples of spiral nebulae, of which there are several, one cannot help thinking of Lord Rosse, and the correctness with which he delineated these objects, though his views at the time were not generally accepted by astronomers. These most interesting nebulae will repay further study, perhaps, more than any other.

Some of the cluster photographs are too much enlarged for the ordinary distance at which one reads a book, but the proper effect can be obtained by looking at them about three feet away. All the photographs are about as good as it is possible to take with an instrument of the size used by Dr. Roberts, and the present dry plates; better photographs can only be obtained by the use of a larger telescope, or by means of dry plates that will, with the same or greater sensitiveness, give a finer grain. This is shown by a comparison of the photograph of the cluster M. 5, taken by Dr. Roberts, with one taken with a larger telescope of a similar kind. Dr. Roberts states (p. 91) that "the cluster is enclosed in dense nebulosity about the centre, the nebulosity hides the stars, even on the negative"; but an inspection of the photographs by a larger instrument shows that the stars are quite distinct, though the exposure was very much longer, a result that might fairly be expected.

A comparison of photographs of this object, taken at different dates, shows that many of the stars of this cluster are variables, and of course it is just possible that there may be variability in the central portions.

Excellent as are the paper reproductions of these photographs, they cannot give all the beautiful detail to be seen on the original negative of a nebula. If change be taking place, it is more than likely that it may be seen in the finer detail first, in which case the original negative must be seen. This points to the absolute necessity of preserving the negative where it shall be available in after years. We hope that all valuable originals will find their way eventually to the keeping of the Royal Astronomical Society, which now undertakes this important duty.

This volume shows that Dr. Roberts has spared neither himself nor his purse in fulfilling the task he set himself to do, more than ten years ago. By the great labour and devotion he has shown for many years in carrying out his carefully considered plans, he has set a model for others to follow in taking up a research of this kind, of which there are so many in astronomy, that from the nature of the case can only be well done by those who, like him, undertake it solely as a labour of love.

A. A. COMMON.