LETTERS TO THE EDITOR.

The Age of the Earth.

I am surprised to observe, in the article which Prof. Sollas has written on this subject in your issue of the 4th inst., p. 533, that he speaks with approval of Dr. A. R. Wallace's method of calculating the earth's age. About two years ago (I have only this week's number of NATURE at hand) I wrote to you on this subject, and was under the impression that I had proved the complete fallacy of Dr. Wallace's method of calculation.

To put Dr. Wallace's view briefly, he assumes that deposition within a limited area of, if I remember rightly, 3,000,000 square miles, goes on 19 times as fast as denudation over the whole land area, which is 19 times as great, and then argues that the whole maximum thickness of the stratified rocks (and hence the earth's age) could be deposited in 1/19 of the time required to carry away from an equal area of land an equal bulk of material.

The fallacy consists in assuming that a great rapidity of deposit over a limited area can in some way allow of the deposit or formation of sedimentary rocks at a greater rate than that of denudation.

It is obvious that, in a given time, no greater volume of deposits can be formed than the volume of material denuded in the same time. If, therefore, as Prof. Sollas assumes, 1/2400 of a foot of sediment per annum is denuded from the land area, by no arrangement can a land area of equal extent, consisting of sedimentary rocks of the same composition and thickness as those which actually constitute the land area, have been formed as a whole more rapidly than 1 foot thickness over 57,000,000 square miles area in 2400 years. Taking the estimate of Prof. Sollas, viz. 164,000 feet, as the maximum thickness of the sedimentary rocks, and taking the existing land area to be accounted for as 57,000,000 square miles, the time required to form an area of 57,000,000 square miles of rock 164,000 feet thick, at 1/2400 of a foot per annum, is 393,600,000 years, unless the area undergoing denudation was greater or less than it is at present (and it could not be four times as great as at present). No concentration of the deposit over a small area would shorten the time required by a single moment.

BERNARD HOBSON.

If, in the compass of a short article, I did not allude to the controversy which followed the attack made by Dr. Hobson (NATURE, vol. xlvii. p. 175, 226) on Dr. Wallace's method of estimating the age of the stratified series, it was because I thought, as I do still, that the honours of that controversy rested entirely on the side of Dr. Wallace.

There is no fallacy in Dr. Wallace's argument, but a strange misconception on the part of Dr. Hobson, which arises from his consistent disregard of the word *maximum* as prefixed to the estimated total thickness of stratified rocks. It is obvious that stratified systems cannot have a *maximum* thickness everywhere over the whole 57 million square miles of the land surface. As a matter of observation, a system attains its maximum thickness over a very limited area, and over a large part of the 57 millions of square miles of land surface it has no thickness at all, or, in other words, is entirely absent. If "maximum" could be made to mean the same as "average," no doubt Dr. Hobson's contention would hold, but those who have made use of a maximum in estimating the age of the stratified series have observed a strict distinction in the application of the two terms.

Rathgar, April 9. W. J. SOLLAS.

Polyembryony.

In connection with the note in the last number of NATURE on the above, I think it should be known that the phenomenon was incidentally observed some two years ago in the red beet (*Beta rubra*) by the late Mr. Romanes and myself. We found that a single seed might produce as many as four distinct plants, and as far as our observations went, polyembryony was quite the normal condition. It seems to be more characteristic of the Gymnosperms than the Angiosperms, and has of course been investigated in the former, and in the latter among the Monocotyledons (Tretjakow) and Dicotyledons (*e.g. Citrus*-Strasburger). The fact of its occurring in such a common type as *B. rubra* should, I think, be taken advantage of by some botanist, as the results could not fail to be both interesting and important. Tretjakow's discovery that the supernumerary embryos in Monocotyledons may be produced by the antipodal cells, certainly suggests his comparison between such embryos and those produced by [parthenogenetic?] apogamy on the prothallia of the lower plants.

FRANK J. COLE.

IMPROVEMENTS IN PHOTOMETRY.

Nearly sixty years have passed since it first occurred to the philosophic mind of Sir John Herschel to attempt an arrangement of the relative brilliancy of the stars, upon a method that should be more secure than the eye estimations that had done duty for many centuries. It is not necessary to enter into any description of his method, which may be regarded now as entirely superseded. Doubtless, had he been surrounded by skilled workmen, furnished with better tools, the cumbrous method employed would have been simplified, but the establishment of an observatory remote from the assistance and contrivances of the workshop is not without drawbacks, as he and others since have discovered and regretted. About the same time, Seidel, in Germany, was at work on the same problem, and the fact that two astronomers, independently of each other, undertook the solution of the same problem, is a proof that it was ripe for mature consideration, while the series of astronomers who have laboured in the same path confirms the suspicion that this kind of investigation too long neglected offered a field having a rich prospect of reward.

But a photometer at once convenient and capable of general application to the stars remained to be invented, and this want was effectually supplied by Zöllner, who proposed a form of construction which has certainly obtained the most general use of any of the suggestions that have been from time to time put forward by astronomers, who have recognised its deficiencies and tried to remedy them. The distinguishing characteristics of the Zöllner photometer are the introduction of an artificial star formed from a lamp shining through a small aperture, and the controlling of the light of that star by means of polarisation. This principle is now of such general use that no lengthened description is necessary. But to explain the reason for the introduction of other forms of photometer, it is necessary to point out what are, or what were, considered to be its defects by those who first used the instrument, defects which it is believed care and experience have since done much to diminish, if not entirely to remove. A source of error might be anticipated in the varying brilliancy of the lamp employed to form the artificial star, and in the early days of the instrument this was a fruitful source of annoyance. Next, the light of the lamp had to strike no less than twenty-eight surfaces, and apart from the difficulty of getting so many surfaces true, and ensuring the parallelism of the Nicol prisms by which the diminution of the artificial star is effected, there is also to be considered the inevitable loss of light at so many surfaces. One consequence of this is that the brightest stars of the heavens are apt to be brighter than the artificial star, and since the observation is made by reducing this light to match that of the real star, it is necessary to have recourse to some such expedient as reducing the aperture of the telescope. And then a difficulty is encountered which has not yet met with a complete explanation. The light deducted from the star, as seen with a reduced aperture, does not coincide with that which would be predicted from theory. In some of the recent series of observations the differences between observation and theory are as great as they are perplexing. "There can be no doubt," wrote Mr. C. S. Peirce, of Harvard, twenty years ago, "that the errors introduced by the use of these diaphragms are by far the most serious of those by which my observations are effected." Dr. Wolff met with similar difficulties, and doubtless anomalies such as these have encouraged the production of other photometers which should be free from the suspicion of error. Having regard to the photometric work actually accomplished, we may confine attention to two forms of apparatus known as the Pickering Meridian Photometer and the Pritchard Wedge

Photometer. In the first of these the principle of polarisation is still used, but the artificial star is discarded. This is apparently an advantage, but it is a question if it does not introduce an error as large as that which it seeks to eliminate. An image of a star, as Polaris, is used as the constant of comparison, and this image can be reduced by polarisation till it equals that of the star of which the magnitude is sought. A lack of resemblance between the stars under consideration is removed, but the removal is effected by the introduction of a second object-glass with evidently different optical capacity, requiring a fresh constant to be determined. Prof. Pickering's photometer consists practically of two telescopes, placed at right angles to the meridian, and over each of the object-glasses is placed a right-angled prism. By means of the northern prism the image of Polaris is reflected, and by suitable adjustment can be made to occupy any convenient position in the field of view, while the prism on the other object-glass can be set to any declination so as to bring the image of any other star, when on or near the meridian, into juxtaposition with that of Polaris. Ingenious arrangements are introduced to ensure the coincidence of the pencils forming the images to be compared, and a control over the accuracy and efficiency of the whole is secured by contrasting the brilliancy of Polaris with itself—that is, by comparing the images formed by either object-glass. This is effected in all cases by rotating a Nicol prism in the eye-piece of the telescope through a measurable angle, and thus equalising the lights of the stars by means of varying the planes of polarisation. How effective this instrument has proved itself in the hands of Prof. Pickering, we shall presently see.

But either of these forms of photometer is necessarily a special production, and therefore the object-glasses are small and the light-gathering powers limited. In Prof. Pickering's first photometer, the aperture was only 4 c.m., with a magnifying power of only fifteen diameters. Prof. Pritchard, considering this limitation a defect, directed his attention to the construction of a photometer which should be readily available on any instrument, and be applicable to stars of very varying degrees of brightness. For this purpose he had recourse to the principle of extinction of the light of a star, by means of a wedge of neutral-tinted glass, which could be moved over the image of a star till its rays were lost by the gradual increasing thickness of the medium through which they had to penetrate. This principle had been used by the late Mr. Dawes, and also by Capt. Abney, but the long-continued use of such an apparatus by the late Savilian Professor is likely to connect his name with this form of photometer. The main defects in its construction arise from the difficulty of obtaining an absorbing medium equally operative throughout the entire length of the spectrum, and also that of determining with certainty the coefficient of absorption—in other words, how much light is lost by the difference of thickness corresponding to one inch in length of the wedge. Recent and more exact methods than those employed by Prof. Pritchard seem to show that the constant used in his work is in error, and that a correction to his magnitudes so obtained is necessary. But it is a peculiarity of the form of construction and method of observation adopted that such a correction can be very easily applied.

These forms of photometers, the Zöllner, the Pickering, and the Wedge, are the three instruments which have been most generally in use, and with which the modern work has been accomplished. The rapidity and the progress of this class of observation can easily be shown by a few statistics. Previous to their introduction, exact photometry was limited practically to two catalogues. Exact photometry is, of course, a relative term; it is meant to include observations other than eye estimations, and therefore Herschel and Seidel, the one with 69 stars, the other with 208, are the only two observers to whom it is necessary to refer. Since the introduction of the more rapid methods, and possibly from a better appreciation of the importance of the inquiry, we have had many extensive catalogues. Leaving out Zöllner himself, who did not attempt to condense his observations into catalogue form, we have—

Peirce's Harvard Catalogue of	494	stars.
Wolff's First Bonn Catalogue of	475	,,
Wolff's Second Catalogue of	923	,,
Potsdam Photometric Catalogue of	3522	,,

All these catalogues have been made by means of a Zöllner photometer, but the list in no way exhausts the photometric work that has been done by this instrument. For instance, Lindemann, at Pulkova, has carried out a long series of observations with the view of determining the scale that has been unintentionally adopted in the record of eye estimations in various catalogues. Ceraski and others have been at work on variable stars, while interesting inquiries into the extinction of light by the atmosphere and other physical investigations have been made by its aid. A debt of gratitude, therefore, of no common kind is due to the ingenuity of Dr. Zöllner. Confining our attention, however, solely to the compilation of catalogues, we have with the Pickering meridian photometer a collection of the relative magnitudes of 4260 stars, followed by a photometric revision of the Durchmusterung of Argelander, in which are given the magnitudes of some 17,000 stars. This leaves out of the summary a quantity of miscellaneous work on the Pleiades, on the Asteroids, on double stars, standard stars, &c. In fact, Prof. Pickering has placed it on record, that the number of measures made with the Nicol prism was up to 1890 slightly under half a million. Finally we have the more modest catalogue of Prof. Pritchard, embracing 2647 stars, and, to complete the record with this particular instrument, we must add a small item of some 45,000 extinctions made at Harvard under Prof. Pickering's direction. Of course, many stars are common to all the catalogues, but the record shows that in the last few years instrumental photometry has been applied to something like 30,000 stars. It is not easy to form an adequate conception of so much activity.

But if the numbers have increased in such welcome proportions, it may be asked is there an equally gratifying advance in the accuracy of the observations? This question is not so easily answered. Doubtless there is a much greater accord among the observations found in the same catalogue, and made by the same observer, employing the same instrumental means. But when these catalogues are compared with one another, large and provoking differences are sometimes encountered, and not a small portion of time has been given by various astronomers to the investigation of these differences, and the attempt to systematise the various recorded values of lustre. But when all has been done, there still remain individual differences which baffle explanation. They seem to point either to irregular variations of brilliancy in the stars themselves, or to baffling meteorological influences, which it is impossible entirely to eliminate. The suggestion has been made by others, and it is intended here to give it the fullest support, that a far larger number of stars exhibit variations of lustre than are included in our variable star catalogues. It must be remembered that these catalogues have been formed, and the variations detected, by the eye alone—that is to say, without the advantages of a photometer. Consequently it is only the larger variations that have attracted attention. It is not easy to establish the fact of an alteration in brilliancy, if it be small, either with or without a photometer; but it seems not unlikely that as star magnitudes gain in trustworthiness, a larger addition will be made to the stars recognised as variable. To come, however, to actual facts, it is recorded in the latest published catalogue of magnitudes, that of Potsdam, that the probable error of the concluded magnitude is 0·04 mag. This amounts to the same thing, practically, as deciding between the illuminating power of 25 and 26-candle gas. It is not known whether such a problem would offer any difficulty to gas experts, but even they sometimes fail to gain full credence from the public.

But the record of photometric research is by no means exhausted by this catalogue of work, limited to the application of specially devised photometers to the stars directly. Another and entirely different method of investigation has been actively prosecuted in the last few years, and apparently with the greatest success. This method avails itself of the refinements and the results of photography. Every one knows the appearance of a photographic plate on developing it after it has been exposed in the focal plane of a telescope for a longer or shorter time. It is seen that the circular images of the stars impressed differ greatly in size, and it may be in depth of deposit, according to the magnitude of the stars impinging on the plate. Consequently, by appropriate means of discussion we are able to determine the relative magnitudes of the stars themselves. And since we have here to contemplate the measurement of a sensible area, it may not be unwise to recall the fact that the term "magnitude" of a star is strictly limited to its brilliancy. Magnitude, therefore, in its accurate astronomical sense, is not easy of definition; difference of magnitude, involving as it does difference of brilliancy, is, however, easily apprehended, and it is a difference of magnitude that is sought to be determined by measurement of the blackened area corresponding to the star images on the sensitised film.

The problem here offered for solution is not precisely the same as that in the direct application of a photometer to the light of the stars. The eye ceases to be the actual photometer employed. For the impression on the retina we have substituted the impression recorded on the photographic film. This film may be more or less sensitive to some of the rays that go to make up the whole of the light of a star than is the ordinary retina, and consequently the record will differ in individual cases from that obtained by photometric means in the more ordinary sense of the word. Leaving out of the question orthochromatic plates, which are not usually employed in recording the positions of stars, the films are prepared so as to be most sensitive for the violet light of a star, whereas the eye is generally most sensitive to the yellow. If object-glasses are employed, this difference is usually aggravated again, for the optician seeks to make this coloured light most operative, according to the direction in which the telescope is to be employed. In the case of a photographic telescope, the rays about G in the spectrum are most important; in the visual telescope, those rays about D. In whatever way the photographic observations are discussed, with the view of ensuring a general agreement with photometric results, it must be anticipated that exceptional cases will differ, especially when the star light is rich in violet rays. Speaking generally, while a photometer, as usually employed, seeks to arrange the stars according to their appearance to a normal eye, a photographic determination of relative brilliancy exhibits the stars as they would appear to an eye most keenly sensitive to chemical rays.

The method of deriving the photographic magnitude will differ according to the manner in which the observations have been made. In the first place the ordinary plate, whether it be taken with the view of producing a general chart of the heavens, or the accurate representation of any small selected area on the sky, will contain implicitly the magnitudes of the stars impressed. Consequently, if we measure the diameter of the circular images produced by the stars of known magnitude, we have a relation between diameter and stellar magnitude. Such attempts end in the derivation of a convenient formula of interpolation. We may find that an expression of the form $m = a - bd$ or $m = a - b \log d$ (where m and d are respectively magnitude and diameter and a and b constants applicable only to that plate, and available only through a small range of magnitudes) is serviceable practically, but has no physical meaning. The determination of the constants a and b is troublesome, and demands a previous knowledge of the photometric magnitudes of some of the stars on the plate—information not always at hand. For these reasons attempts, more or less successful, have been made to assign the magnitude of a star from a knowledge of the diameter of the image and the duration of exposure. To be completely successful such an inquiry demands an acquaintance with the manner in which the image grows on the sensitised film, and this inquiry has progressed but slowly, and is still incomplete. In the early days of photography, it was supposed that the diameter varied as the square root of the time of exposure; later, with the modern dry plate, the fourth root of the time was thought by some to more nearly express the rate of growth; but Prof. Turner and the Astronomer Royal have both shown that neither of the suggestions is satisfactory. The character of the plate, the steadiness of the image, and the accuracy of "driving" (that is, the successful removal of the effects of the earth rotation), all enter as perplexing variables in a research of this character. The Astronomer Royal has suggested that the square root of the diameter of the photographic image increases as the logarithm of the time of exposure. This may be applicable to a particular telescope and through a definite range of magnitudes, but is scarcely likely to express a physical law. But, accepting such a result as a working hypothesis, we cannot pass directly to the magnitude of stars without making another assumption with regard to the diameters. This is usually summed up in the expression that for equal diameters—

$$\text{Exposure} \times \text{brightness} = \text{constant}.$$

That is to say, in order to get equal diameters of the images of two stars, one of which has four times the light of the other, we must expose the plate to the fainter star four times as long as to the brighter. This sounds almost axiomatic, and was for a long time accepted as a demonstrated fact. So much so, that at the Paris Conference in 1889 it was decided that the proper time of exposure to photograph eleventh magnitude stars was six and a quarter times that required for a ninth magnitude star. This decision of six and a quarter was adopted because this number expresses the ratio of the light in a ninth magnitude star to that in the eleventh. Probably no great harm will come from the adoption of such a resolution, but Captain Abney has given good reasons for doubting the assumption that length of exposure and intrinsic brightness are equally operative in producing the same photographic effect. All this goes to show that the determination of magnitude from an examination of the small circular dots on a "star plate" is not at all a simple problem. There is, too, another fact which should be borne in mind. All the discs are small, and yet in a range of five magnitudes, one hundred times more light has gone to make up the larger than the smaller of the two discs. This means that the scale is much contracted, and will probably interfere with final accuracy, quite as much as a want of definiteness at the edge of the disc, or distortion from a circular shape by being photographed at a distance from the optical axis, or other causes which make the measurement of the exact size of the blackened area, uncertain.

It is a question if the problem be materially simplified when the plates are photographed with the direct purpose of determining magnitude. We should then probably adopt a plan which has been extensively employed by Prof. Pickering, but so far has had few imitators. This consists in photographing the trail of a star. If we leave a phototelescope at rest with a plate exposed, the stars describe circular arcs on the plate having the pole as a centre, and having a length of 15° for each hour of exposure. The linear length will vary according as the star is near or remote from the equator, and since the energy is distributed over this varying length, polar stars will produce more intense trails than those stars of equal brightness near the equator. Effectively if two stars are found giving trails of equal density, the brightness of the two stars varies as the cosine of the declination. But if it be found that the stars near the equator travel, by reason of the earth's rotation, so rapidly across the plate that the fainter among them leave no trail, it is possible to give such a rate to the driving clock that the trail may be of any definite length, and the energy concentrated for a longer or shorter time over this space.

The method of deriving the stellar magnitude from an examination or measurement of these trails will be best understood by considering the case of the polar stars. A plate was exposed to the pole for ten minutes, and the telescope left stationary. The aperture was then reduced by successive amounts, so that theoretically any star would appear one magnitude fainter. In the case of a selected star, therefore, we have the thickness of the trail corresponding to known magnitudes, which could at once be compared with the trails formed on other plates. Actually these trails, corresponding, it is presumed, to stars of known magnitudes, were brought into juxtaposition with the trails of stars whose magnitude was sought, and the brilliancy was decided by equality of appearance. Of course similar practices could be and have been pursued when the stars are represented on the plate by means of circular discs. By varying the length of exposure in the photograph of a star of known magnitude, we can approximate to the appearance that stars of any magnitude would present for known durations of exposure. But here difficulties connected with the sensitiveness of the plate, and the meteorological circumstances of the night affecting the transparency of the atmosphere, have to be taken into the account, and the effects eliminated from the observation as carefully as possible, so that it is doubtful if a higher degree of precision results than in the case of photometric observation. There is, however, the obvious advantage that the photographs remain, and greater leisure and further experiment may suggest improved methods of observation and reduction, that shall ultimately give us all the accuracy needed in investigations of this character. The process as at present employed by Prof. Pickering appears to be fairly rapid. Three or four years ago he could report that he had applied his method to over 60,000 images, and the accuracy appears to be about as great as in the case of photometric observations. The chances of systematic error are probably greater.

NOTES.

AT Marlborough House, on Tuesday, in the presence of the Council of the Society of Arts, the Prince of Wales presented to Sir Joseph Lister, Bart., the Albert Medal accorded to him by the Society for "The discovery and establishment of the antiseptic method of treating wounds and injuries, by which not only has the art of surgery been greatly promoted and human life saved in all parts of the world, but extensive industries have also been created for the supply of materials required for carrying the treatment into effect."

PROF. CHRISTOPHER HEATH has been elected President of the Royal College of Surgeons, in the place of the late Mr. J. Whitaker Hulke, F.R.S.

DR. G. S. BUCHANAN has been appointed to the office of Medical Inspector of the Local Government Board.

THE Croonian Lectures at the Royal College of Physicians will be delivered by Dr. W. Marcet, F.R.S., on June 18, 20, 25, and 27, the subject being the "Respiration of Man."

THE grants lately made by the United States Congress, for the Geological Survey during the fiscal year 1895-96, amount to 515,000 dollars, or £103,000. This sum includes all field and office expenses and salaries.

LAST week, the colleagues and former pupils of Sir William Turner, Professor of Anatomy in the University of Edinburgh, presented him with his portrait, as a mark of appreciation of his services in the cause of science and to the University.

IN connection with the Goldsmiths' Company's grant for researches on the anti-toxin treatment, a Committee of the Royal College of Surgeons of England have recommended a grant of one hundred pounds to Dr. Sidney Martin, for the purpose of working out the action of the anti-toxic serum, when used to counteract the effects of various poisons separated by him from the membrane, and from the spleen, in cases of diphtheria.

WE have already noted that the London Chamber of Commerce are promoting a Bill for legalising the use of metric weights and measures for export trade purposes. In connection with this, the London County Council has just resolved to do all in its power to secure the passing of the Bill during the present Session. In the meantime the Council's inspectors will not interfere with the use of metric weights and measures in the execution of foreign orders.

AMONG the men of science who have died during the past week is Theodor Brorsen, whose name is so well known to astronomers. He was born in 1819, and was the discoverer of five comets, as well as the author of a number of writings on astronomical subjects. Since 1879, he lived in retirement at Norburg, his native place. Mr. J. H. Greener, the constructor of several early lines for telegraphic communication, and one of the most able of practical telegraph engineers, died on Sunday, in his sixty-sixth year.

THE President of the German Meteorological Society has issued invitations for a general meeting of the Society, to be held at Bremen on the 17th, 18th, and 19th inst., when various matters of interest to meteorologists will be discussed. The time of meeting has been fixed so as to fall in with the geographical conference, which will be held at the same place during Easter week, and in which oceanography and maritime meteorology form a prominent part. The subject of south polar investigation is also included in the geographical programme, so that it is anticipated that a large number of scientific men will take part in the proceedings.

THE spring meeting of the Iron and Steel Institute will be held in London on Thursday and Friday, May 9 and 10 next, in the rooms of the Society of Arts. The presidential address will be delivered by Mr. David Dale, and the Bessemer gold medal will be awarded to Mr. H. M. Howe, who will contribute a paper on "The Hardening of Steel." Mr. Stead, of Middlesbrough, will contribute a paper on "The Effect of Arsenic on Steel"; Mr. Sergius Kern, Metallurgist to the Russian Admiralty, will discuss the manufacture of armour-