our desire to be untechnical, building in these matters without foundations, and was not Huxley's original scheme of "Physiography" a really sound guide to nature-study, even if it made its appeal to children somewhat older than those contemplated in the work under review?

Prof. Watts, at any rate, agrees with Huxley, and presupposes, in his geological section, a knowledge of the fundamental constituents of the earth. He refers freely to "silica," "carbonic acid," "minerals," "mica," and even "hydrated silicate of alumina." After all, is there more in this than is expected of the child when he is told to take one quart of milk to James Stewart of Auchencairn and one pint and a half to Mistress Campbell of Drumochter? The milk, the persons, and the farms are realities to him, and are therefore easy of comprehension. Is there any objection to making him equally well acquainted with the fundamental materials of the land? Prof. Watts gives the teacher the essential conceptions of geology, and leaves him to select what is suited to the comprehension of his class. His style is terse and vivid, and the illustrations selected by him, often from the photographs of Mr. Godfrey Bingley, are in every way worthy of the text. Since the principles of geology are so greatly concerned with the form of the earth's surface, the making of maps and models is included in the course, and the use of the plane-table, so attractive to beginners in geography, is explained and illustrated. Several of the technical terms in the chapter on the geological record, "brachiopoda," for instance, are not included in the index to the six volumes of the work; but the author moves on without hesitation—the teacher who undertakes the geological branch of nature-study must be ready to explain such technicalities to his class. Altogether, we cannot conceive a more effective introduction to geology than is here put forward.

To make two small criticisms, in the diagram on p. 210 the relations of the upper series of beds seem unnecessarily complicated by a surface-creep towards the valley on one side; and the chapter headed "Igneous Rocks" is mainly concerned with clastic rocks and earth movement. Since the conclusions stated are drawn from observation in our own islands, glaciers and volcanoes are more lightly treated than in many popular works. Prof. Watts has not gone out of his way to be popular, and has succeeded in being so in the highest of all senses.

Prof. Walther, in his "Vorschule der Geologie," has set much the same goal before himself. In five years his simple little book has run into four editions, and still forms a treatise that can be easily slipped into the pocket. The author is one of a band of German leaders in education who wish to see geology taught in all secondary (*höhere*) schools. He here leads on his reader to observe nature out of doors, and in a number of practical exercises shows the varied activities and changes on the surface of the earth. His diagrams are equally simple and convincing, whether of a tree forced to modify the form of its stem through the down-creep of a talus (p. 11), or of the formation of a granite tor (p. 29) by successive stages of decay. Even Dr. Newbigin would shake her head over Prof. Walther's rain-gauge (p. 42); but his charming directness of style gives one great confidence in his experiments. He permits us chemical formulæ, and even crystallographic systems; yet his work is quite unlike the text-books familiar in German schools. His little local sketches, such as the section of a swampy area in Fig. 30, are real lessons in geography; indeed, we have shown these pictures to a class in the field in explanation of the broad features of a landscape. We may differ with him on small points, such as his treatment of trough-faulting, which surely arises most frequently through the faulting of a fault by one of opposite hade; but he guides us onward from our first observations on a hillside until we can grasp the complexities of a geological map. He expects us to purchase one and use it, and supplies index maps for all the German surveys, with considerable lists of literature to assist our summer holidays. This confidence in the attractiveness of his subject is one of the charms of Prof. Walther's treatise; but we must remember that he appeals to pupils trained by longer working hours than our own, and to the sons and daughters of a people that regards education with respect.

Dr. Haas, in "Die vulkanischen Gewalten," adds one more to Herre's series of popular scientific monographs. The black-letter type, and occasional sentences in the long black-letter style, show that it is intended for general readers beyond the colleges. It is not concerned with personal observation, but contains, logically stated, the results of a wide range of research. The description of a volcano in time introduces us to earthquake problems and the constitution of the earth's interior. Though the writers referred to are naturally for the most part German, the author has read widely, and even quotes (p. 97) Albert Brun's view that the volcanic cloud consists of salts of ammonia. This leads on to an interesting discussion of how volcanoes might be produced without the presence of water in the original igneous mass, and of Stübel's theory of the formation of calderas by magmatic expansion and subsequent sinking of the central areas. There is much in this "popular" work that will be useful to the teacher of geology; and the illustrations of dust-clouds and lava-flows are refreshingly recent, after the oft-repeated woodcuts to which we have become inured.

GRENVILLE A. J. COLE.

THE MEDIUM OF CELESTIAL SPACE.

THE physicist knows well that the problems with which he has to deal are insignificant, or at best subsidiary, when compared with the great questions so intimately connected, What is matter? and What is æther? The astronomer, though he observes the operations of nature on a vaster scale, deals with problems of a less ultimate character. Thus, when he seeks to investigate the properties of that medium in which the solar system and the stars alike are moving, he is far removed from any metaphysical abstraction, and only seeks the answer to perfectly definite, concrete questions concerning the transparency and dispersive qualities of the medium. But if the questions are concrete, they are by no means simple, and though the last two years have seen a simultaneous attack on the problem on several converging lines, the main result has been to make us realise the immense difficulties which lie in the way of a definite conclusion.

Whether there is a general absorption of light in space, from whatever cause arising, is a point which suggests itself most obviously. Without attributing any absorptive power to the æther itself, it is easy to see reason for inferring that a loss of light does take place. The streams of meteors which enter our atmosphere have not always been within the sphere of influence of the solar system, but have probably come in incalculable numbers from outer space. There is a continual drain on the atmospheres of the sun and planets owing to the loss of the fastest-moving molecules. The empty spaces which have been found to exist in the midst of the densest star clouds, and the curious rifts which interrupt the continuity of certain bright nebulæ, suggest the presence of obstructing nebulous masses such as that which was only revealed by the outburst of Nova Persei. It is thus reasonable to suppose that a sensible amount of absorbing matter exists in space. But to form a quantitative estimate of its effect is a task of which our increased knowledge makes us only the more appreciate the difficulty.

The problem would be simpler if we could accept the conditions supposed by the earlier astronomers. For them the extent of the universe was indefinitely large, and the distribution of the stars roughly uniform. Moreover, they imagined that the intrinsic brightness of all stars was nearly constant, and that the observed differences of magnitude were almost entirely attributable to the effect of varying distance. But for an effective general absorption we ought, in these circumstances, to expect the whole sky to shine with the average brilliance of a stellar surface, and Halley, in supposing otherwise, was guilty of a simple error. The truth of this was perceived by Cheseaux (1744), and later by Olbers (1823), and both astronomers inferred an extinction of light in space without estimating its amount, or even supporting it by direct evidence, rather than admit that the universe was finite. The first estimate based on these premises was given by W. Struve in his "Études d'Astronomie Stellaire" (1847), a work of great historical interest. Using the data provided by Herschel's gauges, and the counts of Bessel and Argelander, Struve concluded that light coming from the mean distance of sixth-magnitude stars suffered a loss of 8 per cent. of its intensity. But we have ceased to regard as valid the premises on which this conclusion was based. We know now that the variability of the intrinsic light of the stars is so great that distance can no longer be considered as the chief factor in determining their apparent magnitudes. There are also grave difficulties in the way of assuming that the universe extends with finite density to an infinite distance. Seeliger has pointed out that unless the Newtonian law of gravitation be modified, an infinite strain will exist at every point; and even if the smallness of the total light of the sky be accounted for by some kind of absorption, a thermal difficulty remains; for any part of an infinite and eternal universe will be, as it were, within an isothermal enclosure, and the temperature at every point will be at least 6000° C. Such considerations, and the facts of observation, have led us to abandon the idea of an infinite universe, and Newcomb asserted, not only that the system of the stars was finite, but that there was no evidence that any extinction of light in space occurred. That will not hinder us from seeking for evidence. If we possessed a knowledge of the spatial relations and the luminosities of the stars, if, in a word, we held the key to the sidereal problem, we should be in a position to assess the absorption of light in space. But without assessing the loss of light according to distance, the sidereal problem cannot be solved. In fact, the two problems are interdependent, and it may be long before a satisfactory solution is reached.

There is, however, a subsidiary line of attack possible. The absorption may be selective in its character, or, in other words, its amount may be a function of the wave-length. This will be the case if it is due to scattering by particles the dimensions of which are of the order of a wave-length of light. It is not absolutely clear that a similar effect may not be produced by the æther itself. In either case a corresponding dispersion is to be expected, and the rate of propagation will depend on the colour of the light. If any celestial phenomenon be carefully observed which is strictly localised in space and in time, the relative rate of transmission for different parts of the spectrum can be detected. Newton approached the subject from this point of view, and suggested the eclipses of Jupiter's satellites as suitable phenomena for investigation. It is well understood now that the conditions of a gradual eclipse are quite unfavourable for the detection of subtle colour changes, and the distance in this case is altogether too small. The circumstances of stellar aberration have also been invoked to set a limit to the possible dispersion. But the sensitiveness of this test is also too small, for a difference of as much as one-half per cent. in the rate of transmission would at best produce a spectrum $0{\cdot}1''$ in length (and this is about the estimated width of the fine micrometer wire of the largest refractors). As nothing of this order is to be looked for, a finer test must be sought. Arago conceived the possibility of detecting a change of colour in variable stars according to the light phase. Contenting himself with the simple inspection of certain variables, he concluded that there was no such effect. As a matter of fact, more careful observers have noticed a change of tint accompanying the change of brightness; but even so the natural explanation is to be found in the physical character of the stars. This illustrates the need for a cautious interpretation of results, as well as for the most careful and refined methods of observation.

A great advance in practical methods has been made recently by M. Nordmann, of Paris. His plan has been to study the light curves of certain variable stars, using the light from different regions of their spectra, in accordance with the belief that a sensible dispersion in space must produce a want of simultaneity in the respective curves. With this object in view he designed an ingenious modification of the Zöllner type of photometer. By its means the light of the star examined can be compared with an artificial star produced by condensing on a small hole the light of an Osram lamp fed by a constant current. Before entering the eyepiece, the light from both images passes through one of three liquid light filters, and thus the comparison is made in red, green, or blue light as desired. Whatever opinion may be formed of the validity of M. Nordmann's conclusions, it is fair to say that his apparatus has been admirably designed, and that much is to be expected from the systematic application of his method to the study of coloured and variable stars. Finding the atmosphere of Paris unsuitable for delicate researches of this kind, he took his apparatus to Biskra, in Algeria, where he spent several months in 1907–8. Unfortunately, the climate of this station did not fulfil expectations, owing to the prevalence of sand storms, and this fact may account for a certain want of continuity in the observations in a research which demanded continuity as a necessary condition of complete success.

M. Nordmann studied chiefly the stars β Persei and λ Tauri. But before alluding to his results, we may refer to the nearly contemporaneous work of M. Tikhoff, of Pulkowa. M. Tikhoff has conceived more than one ingenious method of attacking the problem of dispersion in space. One of these is in principle the same as that of M. Nordmann, but differs from it in employing photography instead of direct visual estimates. By using bathed plates, the region of the star examined is photographed through certain screens, which are prepared in such a way as to allow only light belonging to restricted ranges in the spectrum to be effective. Thus, an orange screen may be expected to give results comparable with those obtained by visual methods, while a blue screen will give photometric estimates in the ordinary photographic region of the spectrum. By this method M.

Tikhoff studied the variables RT Persei and W Ursæ Majoris. Some years previously he had compared the velocity curves and the light curves of the stars δ Cephei and η Aquilæ, which are well-known spectroscopic binaries and variable stars. Inasmuch as an accepted theory of the physical nature of stars of this type is still wanting, this method must be considered radically unsound. But more recently M. Tikhoff has had the happier idea of comparing the velocity curves as determined from lines in separate regions of the spectrum. Theoretically, this would seem to be the method of all those which have been suggested which is the most free from objection. But it is doubtful whether, among the spectrographic observations already made, even of the highest class, suitable material exists for the successful application of the method. It is certainly possible to criticise on definite and practical grounds MM. Tikhoff and Belopolsky's discussion of the case of β Aurigæ.

The results already obtained may be tabulated thus:—

Star	Range μμ	Lag min.	Authority
β Persei	680-450 ...	13 ...	Nordmann
λ Tauri	,, .	30 ...	,,
RT Persei... ...	560-430 ...	4 ...	Tikhoff
W Ursæ Majoris.	625-380 ...	10 ...	,,
β Aurigæ	450-400 ...	10-20 ...	,,

The third column, which alone requires explanation, contains the retardation, expressed in minutes, of some event observed in blue light over what is supposed to be the same event observed in light of greater wave-length. The event in the first four cases is the light minimum of the star, while in the fifth case it is the disappearance of the radial component of the velocity relative to the Sun. Unfortunately, we have no trustworthy determinations of the parallaxes of these stars. Pritchard's values for β Persei and β Aurigæ are near 0·06″, and M. Tikhoff himself has found the parallax of RT Persei to be insensible. Thus we can only note the qualitative agreement in the sign of the lag in all cases, which suggests that blue light is transmitted through space at a slower rate than light of longer wave-length. Yet the results are liable, even on this ground, to serious criticism, which has been expressed forcibly by Prof. Lebedew. It is not surprising that close inspection shows that the data in the case of β Aurigæ are not self-consistent. But in the other cases we cannot be certain that the observed event is really synchronous in its origin for different qualities of light. This essential condition may be nullified by the physical character of the star, as, for instance, by a selectively absorbing atmosphere of the occulting body. Prof. Lebedew is entirely right in suggesting these criticisms, but they do not prove that the medium filling space is without dispersive power; and even if this fundamental question is left open, it is to be hoped that researches will be continued on the same lines, for the ingenious methods of MM. Nordmann and Tikhoff bid fair to extend our knowledge of variable stars in a most helpful way.

Meanwhile the line of direct investigation of a possible selective absorption in space has been followed. If two stars the intensities of which are I_1 and I_2 require exposure times T_1 and T_2 in order to register images of equal density on a photographic plate, we may put (after Schwarzschild)

$$I_1 T_1^p = I_2 T_2^p.$$

A priori we might expect the same effect to be produced by the same incident energy, or $p=1$. As a matter of fact, a number of independent researches have suggested that p is much nearer the value 0·8. This deficiency in the value of p has been attributed to the properties of the photographic plate. But it occurred to Prof. Turner that the fact might have its origin in cosmic causes. He had deduced from the Greenwich astrographic results that "when the time of exposure is prolonged in the ratio of five magnitudes, the photographic gain is four magnitudes." This result, which has been reached by others in more or less the same form, is equivalent to the above statement that $p=0·8$. A number of facts connected with visual and photographic magnitudes could thus be reconciled by supposing that the small particles distributed in space actually produced a selective scattering in accordance with Lord Rayleigh's law.

It seemed as if a crucial test was at hand to try this hypothesis. It was only necessary for M. Tikhoff to apply his light-filters and to see whether the apparent law of photographic action was the same for the blue starlight which affects the ordinary plate, and for the visual rays to which the bathed plate is sensitive. The experiment was immediately made, and the first results seemed to bring a striking confirmation to the hypothesis. M. Tikhoff found that $p=0·67$ to 0·79 for the photographic rays, but that $p=0·91$ to 0·96 for the green-yellow rays. But Mr. Parkhurst, of the Yerkes Observatory, who has made a special study of the subject of photographic photometry, strikes a note of warning. Under conditions apparently similar, he has obtained $p=0·88$ for the ordinary plate, and $p=0·81$ for the bathed plate with colour-filter. These results go in the opposite direction and must be attributed to the different plates (Schleussner and Cramer) and filters employed. Mr. Parkhurst concludes that "if cosmical causes played any part in the matter they would be completely masked by photographic effects."

The inter-relation which has been noticed between the problem of absorption in space and the problem of sidereal structure has naturally engaged the attention of Prof. Kapteyn, who has been the most prominent and assiduous student of the latter question during recent years. He has noticed that the marked deficiency in the numbers of the fainter classes of stars is equally apparent in all directions of the sky. Unless this peculiarity is attributable to the effect of general absorption, we must suppose that the sun is situated at the centre of the universe, and though such a thing is perfectly possible, it is not specially probable. Kapteyn prefers to admit an absorption of light, and provisionally estimated the loss required by the hypothesis of nearly constant star-density as 0·016 of a magnitude for stars with a parallax of 0·1″. More recently he has brought forward an interesting argument of a qualitative kind. Miss Cannon's classification of star spectra distinguishes between two classes which differ only in showing greater or less relative absorption in the violet end of the spectrum. Arcturus is the type of the stars less affected, while α Cassiopeiæ is the type of those more affected in this way. If the property is not intrinsic in the stars themselves, stars belonging to the Arcturus class should be nearer to us than stars like α Cassiopeiæ. Hence the former class should, on the average, possess greater proper motions. Put to the test, 45 stars of the α Cassiopeiæ division gave an average centennial proper motion 11·4″, and 25 stars of the α Bootis division gave 47·1″. Thus the idea is confirmed that the distinction is due to absorption in space. A number of interesting points are involved in this line of argument, and it is to be hoped that it will be further tested by extending its area of application.

Quite lately Prof. Kapteyn has published a second and more extended research on the subject. In this he investigates the amount of selective absorption, and starts from the principle that "the phenomenon must manifest itself in this, that, *ceteris paribus*, the more distant stars will be redder than the nearer ones." As a measure of redness he employs the difference, photographic *minus* visual magnitude, derived from the Draper catalogue and the Harvard revision. It would be profitless to use direct determinations of parallax, for the material at hand is far too scanty and untrustworthy. Hence he derives the measures of distance from his own statistical discussions, which have enabled him to express the average parallax, of a star as a function of its magnitude and proper motion. The necessary data have thus been found for 1433 stars, and separate equations have been formed for the different spectral classes and certain ranges of proper motion within each class. It is impossible here to follow the rather complicated discussion in detail, but the result obtained on certain simple assumptions as to the nature of the scattering of light implies a loss of

0·00867 of total light = 0·00945 of mag. for photographic rays
0·00427 ,, = 0·00465 ,, visual rays

in the case of a star the parallax of which is 0·1″, or the distance of which is 32·6 light-years. Kapteyn considers that these numbers represent lower limits, and finds no difference between galactic and extra-galactic regions of the sky so far as selective absorption is concerned.

Despite the contradictory nature of the evidence, it must be felt that the whole subject is full of interest. It is now receiving the most critical and exhaustive discussion, and the need for fresh material will stimulate original and appropriate observations. It is pleasant to learn from Prof. Kapteyn that the plan of work for the 60-inch reflector on Mount Wilson includes special provision for this line of study. Efforts directed with a serious purpose and pursued with sincerity do not go unrewarded, though the shape of the reward may not always be according to expectation. H. C. P.

NOTES.

THE list of Birthday Honours was published on Friday last, but, as usual, men of science do not figure largely in it. Among the new Privy Councillors we notice the name of Sir William Mather, who has done much to promote technical education. The honour of Knighthood has been conferred upon Mr. H. Hall, His Majesty's Inspector of Mines for the Liverpool and North Wales district, and Dr. A. Hopkinson, Vice-Chancellor and principal of the Victoria University of Manchester. Colonel F. B. Longe, Surveyor-General of India, and Dr. R. T. Glazebrook, F.R.S., become Companions of the Bath (C.B.). Mr. J. H. Marshall, director-general of archæology in India, Mr. C. Michie Smith, director of the Kodaikanal and Madras Observatories, and Dr. M. Aurel Stein, superintendent of the Archæological Survey, Eastern Circle, are appointed Commanders of the Indian Empire (C.I.E.). The order of C.M.G. has been conferred upon Dr. A. D. P. Hodges, principal medical officer of the Uganda Protectorate, in recognition of his services in the suppression of sleeping sickness, and Prof. T. W. Edgeworth David, F.R.S., of the University of Sydney. Mr. C. O. Waterhouse, of the British Museum (Natural History), has been appointed a Companion of the Imperial Service Order.

SIR WILLIAM RAMSAY, K.C.B., F.R.S., has been elected an "Associé Étranger" of the Paris Academy of Sciences, in the place of the late Prof. Alexander Agassiz.

THE Albert medal of the Royal Society of Arts for the current year has been awarded by the council to Madame Curie, for the discovery of radium. The discovery, which was the outcome of Prof. Becquerel's researches into the radio-activity of uranium and its compounds, was made jointly by Madame Curie and her husband, Prof. Curie, professor of physics at the Sorbonne, in 1898. Prof. Curie died in April, 1906, and in May of the same year the faculty of sciences paid his widow the distinguished honour of appointing her his successor. She has since continued, on her own account, the researches she commenced in association with her husband. The Davy medal of the Royal Society was awarded to Prof. and Madame Curie in 1903, and the importance of the discovery has been fully recognised by the scientific world.

THE King has consented to become Patron of the Royal Society of Arts in succession to King Edward the Seventh, who became Patron on his accession, after having filled the office of president of the society for thirty-eight years.

THE President of the Board of Trade has appointed a committee to inquire what degree of colour-blindness or defective form-vision in persons holding responsible positions at sea causes them to be incompetent to discharge their duties; and to advise whether any, and, if so, what, alterations are desirable in the Board of Trade sight tests at present in force for persons serving or intending to serve in the merchant service or in fishing vessels, or in the way in which those tests are applied. The committee consists of the Right Hon. A. H. D. Acland (chairman), Lord Rayleigh, O.M., F.R.S., Sir Arthur Rücker, F.R.S., Mr. Raymond Beck, Captain T. Golding, Prof. F. Gotch, F.R.S., Mr. N. Hill, Mr. E. Nettleship, Mr. J. H. Parsons, Prof. J. H. Poynting, F.R.S., and Prof. E. H. Starling, F.R.S. Dr. W. Watson, F.R.S., and Mr. S. G. Tallents will be secretaries to the committee.

WITH reference to Mr. Winston Churchill's statement in the House of Commons on June 16, "that the time has now arrived when a definite effort should be made to break new ground and set up a higher standard" of safety in mines, we learn that a committee, appointed by the council of the Royal Society of Arts, and under the chairmanship of Sir Henry Cunynghame, K.C.B., is now considering the relative merits of a number of life-saving appliances which have been submitted in response to an offer, under the Fothergill Trust, of a gold medal or prize of 20*l.* for the best portable apparatus for enabling men to undertake rescue work in mines or other places where the air is noxious. The committee of the society is in communication with the South Midland Coal Owners Mine Rescue Experimental Committee, which is also conducting exhaustive inquiries with the view of discovering the most suitable apparatus for use in the South Midland coal-fields.

THE King held his second Accession Court for the reception of addresses at St. James's Palace on June 22. Among the addresses presented were eight from universities and a number from learned societies. The King made special replies to the Universities of Oxford, Cambridge, Edinburgh, Dublin, and London. To the representatives of Oxford University his Majesty remarked:—"It is my desire to follow the example of my father and of Queen Victoria in sustaining and in fortifying those seats of learning on whose prosperity and influence the character and repute of our civilisation largely depend. Among them the University of Oxford, with its world-famous traditions of steadfastness and loyalty, will ever hold an honoured place." The reply to Cambridge University included the words:—"Your famous University may count