safe to say, would include illustrations from other branches of science, as well as my own.

But — and here I ask pardon if I speak of myself — I have been led to review the labors of other searchers from this standpoint, because I had first learned, out of personal experience, that the most painstaking care was no guaranty of final accuracy; that to labor in the search for a truth with such endless pains as a man might bestow if his own salvation were in question did not necessarily bring the truth; and because, seeking to see whether this were the lot of other and greater men, I have found that it was, and that, though no one was altogether forsaken of the truth he sought (or, on the whole review of his life as a seeker, but might believe he had advanced her cause), yet there was no criterion by which it could be told at the time, whether, when after long waiting there came in view what seemed once more her beautiful face, it might not prove, after all, the mockery of error; and probably the appeal might be made to the experience of many investigators here with the question, "Is it not so?"

What then? Shall we admit that truth is only to be surely found under the guidance of an infallible church? If there be such a church, yes! Let us, however, remember that the church of science is not such a one, and be ready to face all the consequences of the knowledge that her truths are put forward by her as provisional only, and that her most faithful children are welcome to disprove them.

What then, again? Shall we say that the knowledge of truth is not advancing? It is advancing, and never so fast as to-day; but the steps of its advance are set on past errors, and the new truths become such stepping-stones in turn.

To say that what are truths to one generation are errors to the next, or that truth and error are but different aspects of the same thing to our poor human nature, may be to utter truisms; but truisms which one has verified for one's self out of a personal experience are apt to have a special value to the owner; and these lead, at any rate, to the natural question, "Where is, then, the evidence that we are advancing in reality, and not in our own imagination?"

There are many here who will no doubt heartily subscribe to the belief that there is no absolute criterion of truth for the individual, and admit that there is no positive guaranty that we, with this whole generation of scientific men, may not, like our predecessors, at times go the wrong way in a body, yet who believe as certainly that science as a whole, and this branch of it in particular, is advancing with hitherto unknown rapidity. In asking to be included in this number, let me add that to me the criterion of this advance is not in any ratiocination, not in any *a priori* truth, still less in the dictum of any authority, but in the undoubted observation that our doctrine of radiant energy is reaching out over nature in every direction, and proving itself by the fact that through its aid nature obeys us more and more; proving itself by such material evidence as is found in the practical applications of the doctrine, in the triumphs of modern photography, in the electric lights in our streets, and in a thousand ways which I will not pause to enumerate.

And here I might end, hoping that there may be some lessons for us in the history of what has been said. I will venture to ask the attention to one more, perhaps a minor one, but of a practical character. It is that in these days, when the advantage of organization is so fully recognized, when there is a well-founded hope that by co-operation among scientific men knowledge may be more rapidly increased, and when in the great scientific departments of government and elsewhere there is a tendency to the formation of the divisions of a sort of scientific army, — a tendency which may be most beneficially guided, — that at such a time we should yet remember, that, however rapidly science changes, human nature remains much the same; and (while we are uttering truisms) let us venture to say that there is a very great deal of this human nature even in the scientific man, whose best type is one nearly as unchanging as this nature itself, and one which cannot always advantageously be remodelled into a piece of even the most refined bureaucratic mechanism, but will work effectively only in certain ways, and not always at the word of command, nor always best in regiments, nor always best even under the best of discipline.

Finally, if I were asked what I thought were the next great steps to be taken in the study of radiant heat, I should feel unwilling to attempt to look more than a very little way in advance. Immediately before us, however, there is one great problem waiting solution. I mean the relation between temperature and radiation; for we know almost nothing of this, where knowledge would give new insight into almost every operation of nature, nearly every one of which is accompanied by the radiation or reception of heat, and would enable us to answer inquiries now put to physicists in vain by every department of science, from that of the naturalist as to the enigma of the brief radiation of the glow-worm, to that of the geologist who asks as to the number of million years required for the cooling of a world.

When, however, we begin to go beyond the points which seem, like this, to invite our very next steps in advance, we cannot venture to prophesy; for we can hardly discriminate among the unlimited possibilities which seem to open before a branch of knowledge which deals especially with that radiant energy which sustains, with our own being, that of all animated nature, of which humanity is but a part. If there be any students of nature here, who, feeling drawn to labor in this great field of hers, still doubt whether there is yet room, surely it may be said to them, "Yes, just as much room as ever, as much room as the whole earth offered to the first man;" for that field is simply unbounded, and every thing that has been done in the past is, I believe, as nothing to what remains before us.

The days of hardest trial and incessant bewildering error in which your elders have wrought seem over. You "in happier ages born," you of the younger and the coming race, who have a mind to enter in and possess it, may, as the last word here, be bidden to indulge in an equally unbounded hope.

A PLEA FOR LIGHT-WAVES.[1]

It is no doubt universally conceded that no era in the world's history has ever seen such immense and rapid strides in the practical applications of science as that in which it is our good fortune to live. Especially true is this of the wonderful achievements in the employment of electricity for almost every imaginable purpose. Hardly a problem suggests itself to the fertile mind of the inventor or investigator without suggesting or demanding the application of electricity to its solution.

If we except the exquisite results obtained in the manufacture and use of diffraction gratings, and the very important work accomplished by the bolometer (a purely electrical invention, by the way), it may well be questioned whether, within the last twenty years, there has been a single epoch-making discovery or invention either in theoretical optics or in its applications.

It is mainly with a view of attempting to interest brother physicists and investigators in this to me most beautiful and fascinating of all branches of physical inquiry, that I venture to present a limited number of problems, and I think promising fields for investigation, in light, together with some crude and tentative suggestions as to their solution.

The investigations here proposed all depend upon the phenomenon of interference of light-waves. In a certain sense all light-problems may be included in this category, but those to which I wish to draw your attention are specially those in which a series of light-waves has been divided into two pencils which re-unite in such a way as to produce the well-known phenomenon of interference fringes.

The apparatus by which this is effected is known by the inconvenient and somewhat inappropriate name of 'interferential refractometer.' As the instrument which I had the honor of describing to the section at the last meeting is simple in construction, and has already proved its value in several experiments already completed and in the preliminary work of others now under way, I may be permitted to recall the chief points of its construction and theory. A beam of light falls on the front surface of a plane parallel piece of optical glass at any angle, — usually forty-five degrees, — part being reflected, and part transmitted. The reflected portion is returned by a plane mirror, normal to its path, back through the inclined plate. The second or transmitted portion is also returned by a plane mirror, and is in part reflected by the inclined plate,

[1] Abstract of an address before the Section of Physics of the American Association for the Advancement of Science, at Cleveland, O., Aug. 15-22, 1888, by Albert A. Michelson, vice-president of the section.

thus coinciding with the transmitted part of the first pencil; and the two pencils are thus brought to 'interfere.'[1] A little consideration will show that this arrangement is exactly equivalent to an air-film or plate between two plane surfaces. The interference phenomena are therefore the same as for such an air-plate.

If the virtual distance between the plane surfaces is small, white light may be employed, and we have then colored fringes like Newton's rings or the colors of a soap-film. If the distance exceeds a few wave-lengths, monochromatic light must be employed. We may confine our attention to the case of two parallel surfaces. Here it can readily be shown that the fringes are concentric circles, the common axis of the rings being the normal passing through the optical centre of the eye or telescope. Further, they are most distinct when the eye or the telescope is focused for parallel rays. In any other case we are troubled with the same perplexing changes of form and position of the fringes as already noted.

If, now, one of the mirrors have a motion normal to its surface, the interference rings expand or contract; and, by counting the fringes as they appear or disappear in the centre, we have a means of laying off any given distance in wave-lengths.

Should this work of connecting the arbitrary standard of length — the yard or the metre — with the unalterable length of a light-wave prove as feasible as it is hoped, a next step would be to furnish a standard of mass based upon the same unit.

Suppose a cube, ten centimetres on a side, with surfaces as nearly plane and parallel as possible. Next suppose a testing-instrument made of two parallel pieces of glass, whose inner surfaces are slightly farther apart than an edge of the cube. The parallelism and the distance of these surfaces can be verified to a twentieth of a wave. Now apply this testing-instrument to the three pairs of surfaces of the cube, and determine their form, parallelism, and distance to the same degree of accuracy. We have thus the means of measuring the volume of a cubic decimetre with an error less than one part in a million.

It does not seem extravagant to say that by some such plan as this we may obtain a standard kilogram which will be related to the standard of length with a degree of approximation far exceeding that of the present standard. The apparatus can also be used in the manufacture of plane surfaces, and in the measurement of co-efficients of expansion.

For all measurements of refraction and dispersion, — for solids and liquids as well as for gases, — and in the determination of the wave-length of standard lines, the accuracy of the measurement of absolute wave-lengths will depend on the accuracy with which the fixed distance can be compared with the standard metre; and this may be estimated as one part in two million.

The results of the remarkable work of Rowland do not claim a much greater degree of accuracy than one part in half a million for relative determinations; while the elaborate research of Bell on absolute wave-lengths claims but one in two hundred thousand.

It may possibly help to realize the very considerable superiority of this instrument over the grating — at any rate, for the class of work in question — if I recall to your attention the fact that by its means it has been possible to show that the red line of hydrogen is a very close double.

Closely connected with the preceding investigations is the study of the effect of the temperature, thickness, and density of the source on the composition of the radiations, as shown by the symmetrical or unsymmetrical broadening of the spectral lines, and the consequent shifting of their mean position. This question has quite recently been taken up by H. Ebert, and the results he has already obtained are very promising. Ebert has established two conclusions, which, if verified, are of the greatest importance: namely, first, that the chief factor in the broadening of the spectral lines is the increase in density of the radiating body; second, that the broadening, in all the cases examined, is unsymmetrical, causing a displacement of the line toward the red end of the spectrum. The importance of these conclusions, in their relation to the proper motions of the heavenly bodies and their physical condition, can hardly be overestimated. The value of results of this kind would, however, be much enhanced if it were possible to find a quantitative relation between the density of the radiating substance and the nature of its radiations. In the case of hydrogen enclosed in a vacuum tube this could readily be accomplished. It may, however, be objected that it would be difficult in this case to separate the effects of increased density from those due to the consequent increase in the temperature of the spark. The problem of the temperature of the electric discharge in rarefied gases is one which has not yet been solved. In fact, it may seriously be questioned whether in this case temperature has any thing to do with the accompanying phenomena of light; and it appears to me much more reasonable to suppose that the vibratory motion of the molecules is not produced by collisions at all, but rather by the sudden release of tension in the surrounding ether.

[1] A second plane parallel plate of the same thickness and inclination is placed (for compensation) in the path of the first pencil.

BOOK-REVIEWS.

The Philosophy of Kant. By JOHN WATSON. New York, Macmillan. 8°. $1.75.

THE present volume consists of a number of extracts from Kant's principal works, — 'The Critique of Pure Reason,' 'The Metaphysic of Morality,' 'The Critique of Practical Reason,' and 'The Critique of Judgment,' — and is intended for the use of teachers of philosophy. Undoubtedly the study of Kant is the best introduction into modern philosophy, and a powerful means of guarding students from falling into a shallow materialism or positivism. The extracts are well selected, and the difficult task of rendering Kant into intelligible English without altering the character of his style too much has been skilfully solved. The book is an enlarged edition of the author's 'Extracts from Kant's Writings,' which was originally printed for the use of his own students. Professor Watson says that he found by experience the results obtained by means of lectures on philosophy very unsatisfactory, as the students did not learn to think for themselves: therefore he adopted the plan of supplementing his lectures by the study of the writings of various philosophers. This is the same method which is so successfully followed at German universities in what are called 'seminaries.' The teacher who will take this course will find Watson's book very useful and convenient, as it contains the salient points of Kant's philosophy.

Latin Accidence and Exercises. By W. WELCH and C. G. DUFFIELD. London and New York, Macmillan. 24°. 40 cents.

THIS book is intended as an introduction to Macmillan's 'Elementary Classics.' The principles on which the authors' plan is based are a thorough and accurate mastery of the elements of the Latin language, and the putting into intelligent practice at once what has been learned, thus avoiding as much rote-work as possible. The examples have been taken largely from the 'Public Schools Latin Primer,' as the latter is most widely used in the higher forms. The authors do not deem it desirable that beginners should learn the conjunctive mood, which, for this reason, has been added in small type at the end of the 'Accidence.' The book is intended to be mastered in two terms.

Elementary School Atlas. By J. BARTHOLOMEW. London, Macmillan. 8°. 30 cents.

THE publication under review belongs to Macmillan's Geographical Series, edited by A. Geikie, who promoted the interests of teaching geography so well by his well-known essay on this subject. As might be expected, the atlas represents a great improvement upon the ordinary English elementary school-maps, the material which is embodied in the maps being carefully selected, and the abominable relief-plate printing being at last discarded, a clear lithograph taking its place. The atlas contains twenty-four maps or plates. The first shows a number of hemispheres: the northern and southern (land and water) and the European and South American. We would gladly miss the last, as it is intended only to show the central position of Europe. The second map is named 'Europe, illustrating Geographic Terms.' This map must be considered a failure, as it attempts the explanation of geographic terms, instead of by means of objects, by that of a highly and wrongly generalized map. The following plate, which illustrates the mapping of a landscape and the influence of reduction, ought