tion to anyone specially interested in this important branch of optics.

Messrs. Adam Hilger showed many of the specialities requiring the highest skill of the optician, such as Echelon and Lummer Gehreke spectroscopes and quartz spectrographs. Among a fine series of surveying instruments, shown by Messrs. Casella, Negretti and Zambra, Ottway, Pillisher, and others, was a divided circle shown by Messrs. E. R. Watts and Son, the graduations of which have been investigated at Charlottenburg for the purpose of checking the accuracy of their dividing engine. The result is that the average error is not greater than half a second, and nowhere reaches two seconds, a notable achievement.

One of the most important commercial developments in optics in recent years has been the growing use of high-class photographic lenses. The intelligent user has discarded the rectilinear, and the production of anastigmat lenses of the highest quality has been encouraged by the rapid growth of kinematography. Anastigmats at very moderate prices were shown by Messrs. Aldis, by Messrs. R. and J. Beck, whose Isostigmar and Neostigmar series are notable as examples of a new and excellent type, by Messrs. Dallmeyer, and others.

In the meteorological section examples of Dines anemometers and the Dines-Shaw microbarograph were exhibited by Messrs. R. W. Munro and by Messrs. Negretti and Zambra, both inventions of the greatest importance.

It is impossible to give little more than the names of some of the seventy exhibitors in the most important classes. The fifty pages of the section dealing with microscopes contain short accounts of the chief products of Messrs. C. Baker, R. and J. Beck, Messrs. Pillisher, Reynolds and Branson, and W. Watson. Among the exhibitors of spectacles and ophthalmic apparatus were the Kryptok and Unibifocal Co., producing bifocal spectacle lenses of two different types, both requiring great skill in manufacture, and Messrs. G. Culver, Ltd., W. Gowlland, Raphaels, Reiner and Keeler, Ltd., and J. and H. Taylor, who had a large selection of interesting oculists' apparatus.

Beautiful examples of special cameras for process work, a type little known to the general user, were shown by Messrs Hunters, Ltd., and A. W. Penrose, Ltd. Modern types of projection apparatus were shown by Messrs. Hughes, Newton, and Reynolds and Branson. Among several interesting exhibits of the latter were projection apparatus suitable for use with ordinary microscopes, and also inexpensive apparatus for the projection of opaque objects, diagrams, &c., a type which might be more generally used for educational purposes and for the use of speakers at the meetings of scientific societies.

The catalogue committee decided to include in the catalogue descriptions of apparatus shown by firms unable to participate in the exhibition. There is, for instance, a very interesting account and illustration of large telescopes of 24 in. and 26 in. aperture, for the observatories at Santiago and Johannesburg, at present in course of erection in the factory of Sir Howard Grubb. Descriptions and illustrations are also given of other special apparatus made by the firm for many observatories in different parts of the world. To teachers and others the catalogue will be of value, and we would especially emphasise again the importance of many of the introductions, which contain valuable information in many branches of optics scarcely procurable from other sources. The catalogue is obtainable from the publishers, *The Electrician* Co., Salisbury Court, Fleet Street, E.C., for 1*s*. 4*d*. post free.

OPTICAL SCIENCE.[1]

INTRODUCTORY.

SEVEN years have elapsed since the first Optical Convention assembled in 1905, under the presidency of Dr. R. T. Glazebrook. Both that gathering and the second one, in which we are now met, witness to the efforts which are being made, not less by those concerned in the industries than by scientific men, to promote the progress of optical science and of optical trade. Like all other industries which depend on the application of scientific discoveries, the optical industry has felt the pressure of the times; and a widespread sense of need that science and manufacture must be associated in an alliance more intimate and more active than heretofore has been the moving cause of both conventions.

DEVELOPMENT.

Seven years is but a brief span in the development of an industry, or in the history of any science. It may well be that in the seven years which have fled since our first convention we have no obvious great discovery to chronicle. But if no optical invention of first magnitude, or discovery of fundamental importance, has been announced, it must not be assumed that there have been no advances. Progress there has been; progress solid and real, all along the line. No branch of physical science can in the present day remain stationary. The workers are too numerous; the rewards of success, whether in the joy of scientific discovery, or in fame, or wealth, are too alluring to permit stagnation. Moreover, the increase of knowledge, the mastery of principles over phenomena, the conquest of the forces of Nature, are cumulative. Every attempt at wider generalisations, even if unsuccessful in itself, provokes new researches, and extends the foundations for further advance. To this truth the science of optics furnishes no exception. The history of optics is scarred with the battles of rival theories, of which the end is not yet determined. It may, indeed, almost be taken as axiomatic that in all efforts to reach the unknown, to advance human knowledge, it is better to set before one's self some directive hypothesis than to work aimlessly. Every great pioneer in physical science has to frame conjectures, and to keep them, as it were, in a state of solution until either confirmed or disproven. He may even have half a dozen rival and mutually destructive hypotheses before him as he works. Truth is not infrequently reached by a process of exhaustion, by honestly following clues that ultimately prove false, since when they are proved to be false the path to truth has been more closely delimited than before. Even positive error in theory has been know to lead to new and valuable results; as when Euler, arguing from the false premiss that the human eye is achromatic, deduced the conclusion that it must therefore be possible to construct by optical means a lens that should be achromatic.

NEWTON AND HUYGENS.

The influence of Newton in science has been immense. His great genius, shown in his "Opticks" in the unravelling of the puzzle of the colours of the prismatic spectrum, and in his "Principia," in laying the foundation once for all of the laws of motion and of the doctrine of universal gravitation, won for him an almost idolatrous regard. We may recall Alexander Pope's couplet:—

> "Nature and Nature's laws lay hid in night:
> God said, 'Let Newton be,' and all was light.'

Even his mistakes—and they were few—were accepted as dogmas, as when he pronounced the dispersive

[1] From the Presidential Address delivered before the Optical Convention on June 19 by Prof. Silvanus P. Thompson, F.R.S.

power of prisms of different kinds of glass to be proportional to their refractive power, involving the impossibility of ever obtaining an achromatic lens. Even after a hundred years the Newtonians out-Newtoned Newton in their antipathy to anything that seemed counter to his views; and their hostility to Thomas Young's doctrine of interference is a matter of history.

Christiaan Huygens, Newton's great contemporary, propounded his wave-theory of light in 1678, though his famous "Traité de la Lumière" appeared only in 1690. Few British students have ever read that rare work; but none can read it without being impressed with the genius of its author. Everyone knows of Huygens as the inventor of the wave-theory of light; but how few are familiar with the contents of the treatise! He expounds the analogy of the propagation of light with that of sound, then points out the essential differences, and develops the geometrical notion of movements spreading in spherical waves. He had, in fact, to take into account six fundamental facts:—(1) The rectilinear propagation of light; (2) the mutual penetrability of two beams where they cross one another; (3) the law of reflection; (4) the law of refraction (which he had learned from Descartes); (4) atmospheric refraction; (5) the finite speed of light, discovered by Roemer in 1676; and (6) the double-refraction of Iceland spar, discovered by Bartholinus in 1669.

The insight with which, by aid of his conception of elementary waves building up an enveloping wave-front, Huygens succeeded in giving a consistent theory, is a matter for wonder and admiration. He availed himself of Fermat's principle of least time, deduced from it the law of sines for refraction, and based on it the geometrical construction for his wave-fronts which now appears in all books on physical optics. It is true that he had no conception of transversality in the movements of his waves, or of the principle of interference, or even of the existence of trains of waves or of wave-length. His wave-theory was far from being the complete doctrine of Young and Fresnel, and belongs to geometrical rather than to physical optics. But the exquisite skill with which he unravelled the intricacies of double-refraction in crystals and the anomalies of atmospheric refraction must excite the admiration of every reader. His speculations as to the ether of space, his suggestive views of the structure of crystalline bodies, and his explanation of opacity, slight as they are, surprise one by their seeming modernness. He detected the double-refraction of quartz, and discovered the phenomenon of polarisation, while frankly unable to explain it. Another section of his book deals with aspherical forms of lenses for focussing light when one surface is prescribed.

ABERRATIONS.

The enormous focal lengths adopted by Huygens for his telescopic object glasses arose from their comparative freedom from aberrations. No actual lens ever gives perfect stigmatic results; and every beginner knows that aberrations are of two classes: those that arise from the polychromatic nature of light, and those which, even when monochromatic light is used, are due to the form of the surface of the lens, and are often—though not very happily—termed spherical aberrations. Newton calculated ("Opticks," pp. 84, 89) that in a 100-foot telescope with suitable aperture the aberration of colour would be at least 1200 times as great as the aberration caused by the sphericity of figure of the object glass. We know, in fact, that in despair at making a lens devoid of chromatic aberration, he gave up refractors and invented his reflecting telescope. But when in 1757 Dollond, by the invention of the achromatic lens, removed the worst of the aberrations, the correction of the aberrations due to form became the next desirable step. Descartes, Deschales, and other writers suggested various devices for grinding lenses with hyperbolic, elliptical, and other aspherical curves; but practical difficulties prevented their use. In the early part of the nineteenth century, Coddington and Airy, the younger Herschel, and others investigated in great detail the aberrations of lens combinations, and brought that part of optics to a high pitch, though much of their work remained unknown outside England.

ILLUMINATION.

During the past seven years there has been great activity in the development of the branch of geometrical optics concerned with illumination, involving questions of the distribution of light, and the measurement of it in quantity and intensity by photometers. Though a better standard source of light than either the Harcourt Pentave lamp or the Hefrer amyl-acetate lamp is still a desideratum, it is satisfactory to know that international agreement upon the unit of light is practically secured, through the collaboration of the four great laboratories at Sèvres, Charlottenburg, Bushy, and Washington. Committees have been actively at work on the questions of minimum illumination required in schools, libraries, factories of various kinds, and in roads and streets. Even the House of Commons has awakened to the fact that the illumination enjoyed by its members is only about half a candle-foot, whereas for comfortable reading it should be two or three times that amount. Photometry has indeed grown since the photometric law of inverse squares was first announced by Deschales in 1674, or since the early treatises of Bougner and Lambert. New forms of photometer have multiplied, and every month sees fresh developments.

PHYSICAL OPTICS.

When we turn to the vast subject of physical optics we cannot but be struck with the variety of phenomena which must be taken into account by anyone who would deal with the nature of light itself, or with the mechanism of the ethereal medium by which it is conveyed. Dispersion[2] and its anomalies, interference, diffraction, the multitudinous effects of polarisation, the problems of radiation and luminescence, of opulescence, and the blue of the sky, of iridescence, and the gorgeous colours of butterflies and humming-birds, to say nothing of radio-activity, or of the chemical, physiological, electrical, magnetic, and mechanical relations of light, furnish whole fields in which knowledge is still in the making.

In physical optics, though there are mathematical laws, such as those discovered by Fresnel and Stokes, to be mastered, the chief concern is with physical phenomena; and the study of these would seem to be inseparable from speculations as to the nature of the luminiferous æther, and from consideration of the conflicting theories as to its constitution. Formerly the vexed question was the mechanical explanation of an æther which should behave like an elastic solid a million times more rigid than steel, and at the same time as a mere vapour a billion times less dense than air. Then there was an outstanding quarrel between the followers of Fresnel and those of Neumann and McCullagh as to whether the vibrations of light were

[2] Herschel, in 1828, in his article "On Light" (Encyclop. Metrop. p. 450), declared: "The fact is that neither the corpuscular nor the undulatory, or any other system which has yet been devised, will furnish that complete and satisfactory explanation of *all* the phenomena of light which is desirable. Certain admissions must be made at every step, as to modes of mechanical action, where we are in total ignorance of the acting forces; and we are called on, where reasoning fails us occasionally for an exercise of faith."

executed in or across the plane of polarisation. Maxwell dissipated the controversy when on his electromagnetic theory of light he showed that both were present, the elastic vibrations taking place across the plane, and the magnetic ones in it.

To-day, and ever since Maxwell propounded the electromagnetic theory, the main interest has been transferred to the question how the æther is related to electricity and to ponderable matter, and whether the motion of matter in space affects or is affected by the æther. Is it a fact that the æther is stagnant, fixed, "while the molecules constituting the earth and all other material bodies flit through it without producing any flow in it"?[3] Or is the æther speeding along with the earth and the whole solar system in headlong and enormous flight? That singular doctrine, now in fashion, called "The Principle of Relativity," invites us first to deny that we can ever detect or measure the absolute velocity of the earth in space, and then to admit that, therefore, since we cannot regard the æther as filling space or fixed in it, we must abolish the notion of the æther as a conveying medium, and must explain the finite velocity of light in some other way depending on electromagnetic principles inherent in the light impulse, and expressed in terms of coordinates the origins of which are to be only relatively, and not absolutely, fixed. Without pursuing these anarchical ideas, we may remark that for all useful purposes it suffices to admit that no terrestrial optical phenomena have any relation to the direction of the earth's motion through the universe.

As for the relation between matter and æther, while for clarity of thought we must frame some idea of the connection between them, we may accept Sir Joseph Larmor's dictum that "Matter may be, and likely is, a structure in the æther, but certain æther is not a structure made of matter." His view that "the motion of matter does not affect the quiescent æther, except through the motion of the atomic electric charges carried along with it," is, of course, bound up with the further conception that the æther is a plenum in which "vortices or other singularities of motion and strain" are the nuclei of which matter consists.[4]

Spectacle Optics.

The fixing of two lenses together to form a pair probably dates from the thirteenth century, but history is obscure. Raphael, in 1517, painted Pope Leo X. wearing concave spectacles. But not all pictures are good as evidence, for there is, or was, in the Chiesa de' Ognissanti, in Florence, a picture attributed to Sandro Botticelli, depicting St. Jerome in his cell, with a pair of spectacles beside him. This does not prove that spectacles existed in the fourth century; and the presence of the spectacles may be as great an anachronism as in another picture of the same Saint is the presence, on the wall of the cell, of a pendulum clock. Coming down to the present day, few persons probably are aware of the rapid rate at which that branch of the subject is developing into a severe scientific study. Perhaps they think that the only progress in spectacle-making has been the introduction of lighter spectacle frames or ingenious dodges for grinding bifocal glasses, or for fusing one kind of glass into another for a bifocal lens, or for grinding toric lenses. This would be quite a mistake. It may be that the teaching in the medical schools has remained much as it was; but the training of spectacle opticians to deal with the problems of astigmatism, both of eyes and of lenses, has taken great strides, and under the stimulus of the system of certification by the Spectacle Makers' Company and of other optical bodies is assuming an important development.

Apart from actual practice, an exceedingly important advance in theory has been initiated by the genius of Allvar Gullstrand. In the year 1903 he pointed out that the centre of rotation of the eyeball does not coincide with the nodal point, which is its optical centre. It is, in fact, from 2 to 3 millimetres behind it, and therefore in all those uses which the eye makes of its power of turning about in its socket the mathematical treatment which assumes it to be fixed is inadequate. The assumptions of the Gauss system are no longer fulfilled, and modifications have been introduced. For precise work this affects the efficiency of spectacle lenses and introduces new sources of aberration. For this reason spectacles should be so designed that the particular point at which they are corrected for radial astigmatism should lie at the centre of rotation of the eye.

One other point in spectacle optics needs attention. Thirty years or more have passed since British opticians ceased to denominate their lenses in terms of inches of focal length, and adopted the dioptric system of numbering, in which a lens having a focal length of 1 metre is described as having a power of one diopter, and a lens of twice that power as of two diopters. The diopter, the international unit of lens power, was adopted in 1875 on the proposal of Monoyer at the Brussels Conference. Nearly thirty years ago it was pointed out that the diopter, being the reciprocal of a length, is in reality a unit of curvature, and may be applied to express curvatures of wave-fronts and of surfaces, as well as the power of a lens, which is, in fact, merely the expression of the convergency which it imposes on the light passing through it.

Optical Education.

To the optical industry as a whole the question of the scientific training of young men who shall hereafter become technical leaders and pioneers is a very serious one, in view of the stress of the times. Men are wanted who can undertake mathematical calculations with a first-hand practical knowledge how these calculations are applied in the design of instruments and who have a thorough acquaintance with the whole range of optics. That training at present they cannot acquire at any of the universities. It is a melancholy fact that now, when this need is sorest, the pursuit of optics at our universities and colleges is in a deplorable state. Except in the Northampton Polytechnic, and one or two other institutes, the study of optics for its own sake is entirely ignored. Not one of the universities of Great Britain has created a chair of optics, though there are professorships and extensive laboratories for electrical engineering, for metallurgy, and for various branches of technical chemistry. In the universities and colleges the only people who are learning optics are merely taking it as a part of physics for the sake of passing examinations for a degree, and care nothing for the applications of optics in the industry. They are being taught optics by men who are not opticians, who never ground a lens or calculated even an achromatic doublet, who never worked with an ophthalmoscope or measured a cylindrical lens.

Again and again, as might be demonstrated by many instances, advances in optics have come about through the association of the highly trained mathematician with the practical workman, and most effectually when these are combined in one individual. But where is England to look for the training up of such men? For twenty-five years some of us have

[3] Larmor, "Æther and Matter" (1900), p. 16?.

[4] Particular reference may be made to Sir Joseph Larmor's "Æther and Matter" (1900), and to Prof. E. T. Whittaker's "History of the Theories of Ether and Electricity," 1910.

urged the need of an Institute of Technical Optics, where students of optics will be trained in optics by men whose work is optics. The need grows year by year. Deputations from the trade have waited on the London County Council, and questions have been asked in Parliament, yet in vain. It has been suggested that two separate schools are needed—one for optical workmen, the other for optical calculators, the latter to be a mere small department in one of the universities or colleges. Such a divorce of practice and theory would be futile. What is wanted is an establishment where the whole atmosphere is one of optical interest, where theory and practice go hand in hand, where the mathematician will himself grind lenses and measure their performance on the test bench, where brain-craft will be married to hand-craft, where precision, whether in computation or workmanship, will be a dominating ambition.

As yet the only attempt made towards this ideal is the optical department of the Northampton Polytechnic in Clerkenwell, where a handful of students are housed in wholly inadequate surroundings. In the future institute the teaching must be thorough and independent, and free from all ulterior domination of examinations. The examination blight, which has cramped education in so many ways, has brought us to this pass, that outside the centre just named there is not a college student in Great Britain who is being trained in *optics for its own sake*. The moral is obvious. The future optical institute must be properly housed and equipped as a self-contained monotechnic, concentrating all its energies on the one aim. On no consideration whatever ought it to be under the baneful influence of a university, where its students would be diverted from whole-hearted devotion to progress by the temptation of degree-hunting. Would that this convention might make it clear to those in authority that the optical industry is in deadly earnest in demanding the establishment of such a centre of optical training.

BIRD NOTES.

IN the May number of *The Zoologist* Mr. J. M. Dewar discusses the evolutions performed by flocks of certain kinds of wading birds of the family Charadriidæ. These evolutions, which are based on a simple type common to the whole family, but frequently comprise specialised additions, are believed by the author to be of a defensive and protective nature, the essential form of movement being an imitation of the sea-spray. "When the flock is large the movements are often sectional, and what seems to be a succession of waves passing through an extended flock is in many cases an extremely quick repetition of the simpler form of the evolutions by sections. The 'sheet-movements' which provide much of the spectacular display are rendered possible by the same circumstance, and generally grow out of the simpler form. . . . In other words, one may say the simpler evolutions are imitative in character and protective in purpose; in the complex evolutions the simpler imitative movements are partially hidden by the development of a wealth of movement which is still protective in purpose, but which, as regards character, is incapable at present of a simple and comprehensive explanation."

Despite the fact that the work of the two sexes can be easily distinguished, it appears from a note in the May number of *Witherby's British Birds* that there is a dearth of trustworthy observations in England to show whether male or female woodpeckers excavate the nesting-hole, or whether both combine in the task. Continental observers are, however, generally agreed that the cock is the worker, and if this be so the same thing doubtless obtains in Britain, despite certain statements as to both sexes of the green woodpecker having been seen at work together.

In completing his notes on the bush-birds of New Zealand in the April issue of *The Emu*, Mr. J. C. M'Lean observes that, inclusive of the bush-hawk and the morepork, twenty-one species of North Island birds may be classed as arboreal, and of these sixteen have been identified in the Maunga-Haumia bush. Possibly two others should be added to the list; but it is probable that the huia—now very scarce everywhere—never extended so far north. The stitch-bird seems to have been exterminated in the district, if not also on the mainland.

R. L.

COMPARATIVE STUDIES IN MELANESIA.[1]

IN the interests of his topographical work the author of the memoir under consideration was obliged to be almost constantly on the move; though this rendered any intensive study of a special people impossible, yet it afforded him opportunities for personal comparison of various peoples and cultures over a wide area. He has worked up the older sources with great care, and in many instances extends his comparisons to America, as he is anxious to see a full treatment of Malayo-Polynesian affinities with South American cultures worked out; the cursory treatment of this vast theme in Graebner's "Bogenkultur" he regards as quite inadequate and faulty in method.

The ethnological section of the memoir (pp. 28–167) deals primarily with western New Britain, of which our knowledge has been hitherto slight, also with the other German possessions in Melanesia, and comparative data from Indonesia and America are added. The physical anthropology is very incomplete, partly through the author's misfortune in losing his apparatus when his boat overturned; head-indices should have been worked out in addition to giving lists of head-lengths and -breadths. As regards material culture, Dr. Friederici has been careful to ascertain the distribution of different objects and customs wherever possible, and he gives a useful account of the various forms of houses observed, and the association of divergent types, with a number of diagrams of dwellings and plans of certain villages. Considerable cultural complexity and wide variation physically are of course to be anticipated in an area situated like the Bismarck Archipelago on the great highway of migration; in fact the author states (p. 316) that a considerable proportion of the natives are directly traceable to the "Alfurus" of eastern Indonesia, whose modified descendants are a relatively recent element in the Bismarck Archipelago and other Melanesian areas.

In the discussion of affinities the author emphasises the importance of linguistic evidence, and the present volume contains a sketch of the grammar of the Barriai language of the northern coast of western New Britain. He makes it a practice to give the native names of cultural objects described, and is a strong advocate of the retention of native place-names, which are already familiar to traders in the locality, and to which after all belongs the priority.

1 "Wissenschaftliche Ergebnisse einer amtlichen Forschungsreise nach dem Bismarck-Archipel im Jahre 1908." II. "Beiträge zur Völker- und Sprachenkunde von Deutsch-Neuguinea." By Dr. Georg Friederici. Pp. vi+324+iv plates+map. (Mitt. aus den Deutschen Schutzgebeiten, Ergänzungsheft Nr. 5.) (Berlin: Ernst Siegfried Mittler & Sohn, 1912.) Price, separately, 3.60 marks.