teaching procedure and of the overt responses of the children to the visual material. (In the full report this will be given in detail.)

Next came the teachers. All four schools had shown a most gratifying willingness to co-operate. Perhaps the most interesting feature of their testimony was the unlooked-for result that, quite apart from the stimulus to the children, the use of these visual techniques had a distinctly stimulating effect on the teachers. The extremely cordial relationship between the teachers, the Visual Education Centre staff and the director of education, Mr. G. A. Tue, was the *sine qua non* of the whole research. The four Exeter schools taking part were the two Episcopal Senior and the two Ladysmith Senior schools.

The lesson notes, tests and visual materials were all on view. The latter consisted of four films and still material consisting of large photographs of high quality, well-mounted, bearing full captions, and covering the four topics. Other material was also demonstrated.

Discussion took place on classroom techniques, on the use of museum material and on the planning of educational films. Miss Grayson (of the British Film Institute) stressed the need for co-ordination. The problem of making museum resources available for the schools was discussed. Mr. Neilson Baxter (Shell Film Unit) pointed to the valuable experience gained by many ciné-technicians in the production of instructional films during the War. Mr. Anstey (Film Centre) urged the setting up of a Government films department. The present author pointed out that if producers would plan educational films in series, each series following a characteristic treatment, a prototype film for each series could be made and tried out by the Exeter technique. The evidence so obtained would provide guidance for the rest of the series. The conference was summed up by Mr. K. de B. Codrington (Victoria and Albert Museum), who stressed the simple common elements which run through all good teaching and the need for using each type of visual material for the purpose to which it is most suited.

General Conclusions

Whatever researches are made on problems of media and methods, the fundamental problems are those of visual matter. Any visual production rests on a whole series of assumptions, conventions and decisions. No amount of technical or æsthetic virtuosity can compensate for a failure to come to terms with the philosophy of curriculum-building or the psychology of the child. One important factor often neglected is the contribution of intellectua security to emotional stability. Our existing curricula present children with an anarchic sequence of incommensurable and unintegrated approaches to knowledge. If visual education neglects its fundamentals, it may easily perpetuate this state of affairs. Theoretical research at the Visual Education Centre is therefore concerned with the bearing of three normative disciplines on visual production, namely, logic, semantics and statistical theory. Visual productions must be consistent, they must present their meaning clearly, and they must take account of the variability which all objects display. This is a long story, to be presented in a larger publication, together with an account of its bearing on the curriculum as a whole, and the significance of these new developments in relation to the teacher's function and to national (and international) educational needs.

MATHEMATICS FOR PHYSICISTS

"MATHEMATICAL teaching," said Klein, "is a function of two variables, the subject and the pupil." In other words, it is necessary to vary the presentation of the subject to suit minds of different types. Nineteenth-century physicists, such as Kelvin and Maxwell, started as mathematicians, and many of the contemporary mathematicians relied upon physical intuition, so at that time a common course of training was possible. The interests of the two parties have now diverged. The pure mathematicians have recognized that intuition may be successful for a long time, and yet lead in the end to a terrible blunder. They now keep to the straight and narrow path of rigorous logic. For example, they do not, like Fourier, assert that any function whatever can be expanded in an infinite series of harmonic terms, but occupy themselves with the difficult task of formulating the precise conditions necessary and sufficient for this expansion.

On the other hand, experimental physicists regard mathematics as a tool, to be used whenever it is convenient to supplement the results of experiment, or as a language in which these results can be concisely expressed. To them Fourier's theorem is merely the mathematical form of a general physical principle, firmly established by experience. Why should they worry about possible exceptions which may never happen ? They prefer vigour to mathematical rigour, which seems to them as devoid of live interest as *rigor mortis*. Even if they could appreciate the need for the purely logical discussion, they would not have time to study it. What has been said of Fourier's theorem applies also to the large amount of advanced mathematics which is inseparably connected with recent advances in physics. The traditional 'mathematics subsidiary to physics' is now quite inadequate, but experimental physicists cannot afford the time needed for a great extension of the mathematical course on its present lines.

To deal with this dilemma, the Institute of Physics and the Mathematical Association have held a conference and issued a joint report, "The Teaching of Mathematics to Physicists" (Institute of Physics, Spencer House, South Place, London, E.C.2). They recommend courses much wider in scope but simpler in technique than the usual subsidiary mathematics. For example, their Schedule A, which is to cover the minimum requirements of a fully trained physicist, includes roughly the contents of both the two subsidiary subjects pure mathematics and applied mathematics (which are alternative subjects at some universities, such as London), with the addition of a little statistics. This doubled syllabus is to be covered in the same time as before, say, one third of the physicist's total study hours for two years. This is to be made possible by omitting the solution of difficult problems, and merely requiring the student to recognize the applicability of the mathematics to physics. Specimen examination questions are given to show how this can be done.

The report also gives a Schedule B, suitable for the ablest undergraduates in their third year, and a Schedule C suitable for the postgraduate stage. At first sight these later schedules seem far beyond the capacity of any experimental physicist; but, as in Schedule A, it is intended that they should be treated with the minimum of technique. It is admitted that this will require special lectures and an increase in university staffs. It is suggested that such lectures might be useful for students of other branches of science, but this has not been discussed in detail. It is recommended that the lecturer should be a member of the mathematics department, with a special sympathy towards the outlook of the physicists.

As a personal comment on these proposals, it may be stated that an optional course on these lines, as a supplement to the usual subsidiary mathematics, has been given for several years at University College, Nottingham. It seems to be appreciated by the stronger physicists, but it is rather a strain on the weaker ones. The surprising thing is that it is enjoyed by mathematicians, who apparently welcome a temporary release from the inhibitions of mathematical rigour. H. T. H. PIAGGIO.

BIOLOGICAL APPLICATIONS OF THE ELECTRON MICROSCOPE*

By DR. G. E. DONOVAN

ELECTRON micrographs may be considered analogous to X-ray pictures, since the darkness and brightness depend on the thickness and density of the specimen; they are unlike micrographs taken with the light microscope, in which an image is formed due to differences in the amount of absorption or refraction within the object. The presence of very small particles in specimens for examination under the electron microscope will cause perceptible scattering, and the image formed of an object thicker than about 0·5 μ is merely an enlarged silhouette.

Another characteristic, which is usually an advantage, is the great depth of focus. This is useful for stereoscopic work.

Specimen Mounting

The vast majority of microscope specimens must be mounted upon a transparent support. Glass of a convenient thickness is the most suitable material when the illuminant is visible light, but it is opaque to an electron stream, and a new technique has therefore been built up, whereby specimens may be adequately prepared for examination. A very thin, uniform film of collodion or nitrocellulose can be produced so as to show no structure, similar to the glass slide used for supporting specimens in the ordinary microscope. It produces a uniform diminution of intensity, but if the film is thin enough, the amount of scattering and spread of velocity caused by it does not cause much interference with the picture. A very thin film is produced by dropping a small quantity of a 1·5 per cent solution of collodion in amyl acetate on water saturated with amyl acetate. The film spreading over the surface is taken up and dried on a small circular disk of 200-mesh wire gauze, less than $\frac{1}{8}$ in. in diameter. Gentle pressure on the diaphragm causes it to adhere to the film. Films of this kind are thinner than the length of a collodion molecule. The coated disks are separated from the rest of the membrane by means of delicate handling tools, lifted from the water, inverted so as to bring the film side uppermost, and placed upon a miniature pedestal. There the water clinging to the surface is removed, and a drop of a fluid containing the specimen in suspension, or solution, is placed upon it, and the fluid allowed to evaporate. The whole is then placed in position on the 'cartridge', which in its turn is inserted through the air-lock into the microscope into the space about to be evacuated. The surfaces of certain materials, for example, metals and alloys, can be studied by light reflected from them in the light microscope, but this is generally impracticable with electron rays. A cast of the surface can be made by using some sort of plastic in solution and allowing the solvent to evaporate; a negative solid replica of the surface structure can be produced by peeling off the film from the original, and can be examined like an ordinary specimen in the electron microscope. An electron image of such a film will develop more strongly where the plastic material is thinnest. In some cases, where a replica cannot be stripped off, satisfactory results can be obtained by dissolving the original in some acid or other solution which the plastic film can withstand. The cast technique may be useful for examining the surface of such structures as metals, teeth, etc.

Practical Applications

Until very recently, the electron microscope remained an experimental instrument in the hands of the physicists, and it is only in the last few years that any serious attempt has been made to exploit its possibilities for research. Most of the examinations so far reported have been directed towards the discovery of possible fields of research, rather than towards the solution of particular problems. It holds great promise in almost every field of science, especially in chemistry, metallurgy, medicine and biology, as it reveals many important structures and reactions which have hitherto been inaccessible to direct observation and measurements.

Dusts and smokes are among the simplest kind of materials to view in the electron microscope, revealing groups of ultra-microscopic particles that float in the air. This type of research is of interest to the public health worker and those interested in environmental diseases, such as the medical man in industry, etc. A great number of the particles found in human lungs are smaller than 5 μ in diameter, and an appreciable portion less than 0·2 μ. Electron micrographs have been published of smoke particles resulting from the combustion of zinc, magnesium ribbon, aluminium, etc. The physical structure of these varies; for example, the electron micrograph of magnesium oxide shows small cubic crystals, aluminium oxide smoke is made up of strings of spherical globules, etc.

Powders are required for many purposes, and a knowledge of their physical structure is of importance. A sample of lead arsenate insecticide which possessed unusual covering power and toxicity showed under the electron microscope, magnification 56,500, that the particles consisted of extremely thin flakes, which naturally possess a large surface and clinging power. A popular face powder owed much of its popularity to the fact that it did not easily come off. The electron microscope showed that its particles were of a highly angular shape, capable of hooking themselves into the epidermis.

The instrument has many uses in organic chemistry; for example, an electron-micrograph has been published[1] showing a specimen of polyvinylchloride. The magnification (100,000) shows the specimen to be mottled with an evenly spaced succession of spots. The spots are considered small enough to constitute single molecules, and there is little doubt that visual

* From a paper on "The Electron Microscope: its Applications to Medicine" read before the Royal Society of Medicine on June 21.