exception of Rothamsted Experimental Station and a few centres in the United States, there existed no other laboratory where experience in so many aspects of plant virus study could be obtained, applications from foreign workers for this training became very frequent. Unfortunately, these activities had to be severely curtailed owing to the lack of laboratory accommodation. Nevertheless, it may be mentioned that students have come to take either research degrees or courses of instruction in plant virus work from Argentina, Australia, Belgium, Brazil, Canada, China, Czechoslovakia, Denmark, Gold Coast, India, New Zealand, Poland, Portugal, South Africa, Sweden and the United States, and visitors have come from all over the world.

In looking back over two decades, it becomes evident how, with increasing knowledge and new technical discoveries, the trend of virus research has changed. In the beginning, most of the emphasis was placed on the disease, and symptomatology was all-important, although the study of the relationships between the viruses and their insect vectors was already being undertaken. The isolation of tobacco mosaic virus by Stanley in 1935, however, was the key which opened the door to the study of the virus itself, quite apart from the disease it may cause. A brief review of some of the main contributions by the Cambridge workers illustrates this change of emphasis in virus research. For the first few years, attention was directed almost entirely towards potato virus diseases, and from this work three items of interest may be noted. The first of these was the identification of the insect vector of potato leaf-roll, which was later also found to carry another potato virus. This was the aphis, *Myzus persicæ*, and it was almost the first introduction to public notice of the aphis which, since that time, has become of paramount importance in the field of plant viruses and seems to be the most efficient vector of these agents in the world. It is now known to transmit more than twenty distinct viruses. The next addition to our knowledge of potato viruses was the discovery of the paracrinkle virus in potatoes of the variety King Edward; this is one of the unsolved puzzles of the virus world, since it is present in all plants of this potato variety, but no method is known by which it can spread in Nature. The case of paracrinkle is often quoted as evidence of the heterogenesis of viruses by those who hold this view. The third item was the analysis, for the first time, of a plant virus complex by differential methods of transmission, and the isolation of the two potato viruses now universally known as *X* and *Y*.

In 1931 the virus of tomato spotted wilt was discovered for the first time in Europe; it was found in an ornamental plant sent to Cambridge from Cardiff. Before this it had not been seen outside Australia. Since then the distribution of the virus has become world-wide, and in Great Britain it is one of the major problems of the tomato grower with 'mixed houses'.

The viruses of tomato bushy stunt and tobacco necrosis, both described for the first time in Cambridge, have proved of great scientific interest. The virus of tomato bushy stunt, about which more is known than of most viruses, was the first to be isolated in a three-dimensional crystalline form, and this was accomplished by Bawden and Pirie, after the former had left Cambridge. Shortly after this the virus of tobacco necrosis was isolated as thin crystalline plates. About this time, also, the comparatively new technique of plant virus serology was applied to the study of potato virus *X*.

In 1938 a new virus complex affecting the tobacco plant, known as 'rosette', was investigated, the chief point of interest being the apparent relationship between the two component viruses. This is suggested by the fact that, while both viruses are aphis-transmitted if they are together in the plant, one of the two cannot be picked up by the insect if the other virus is not present.

During the period 1940–45, several new viruses have been described, those of *Arabis*, *belladonna* and lovage mosaic, tobacco broken ringspot, tomato black ring and of two new potato diseases, veinal necrosis and veinal yellows, which were found in some South American potatoes. Of these new viruses, those of *Arabis* mosaic and broken ringspot are of especial interest, since they appeared in plants inside the experimental glasshouses with no apparent explanation of their origin.

During the last two years an extremely interesting and important new virus has been discovered and studied. Known as turnip yellow mosaic virus, it has been isolated in two different crystalline forms and, like other plant viruses studied so far, it is a nucleo-protein. In addition to the active virus, infected plants also contain a protein which is apparently the virus protein but lacks the nucleic acid. This protein has also been crystallized, and studies of the biological and biophysical properties of these two proteins are now in progress. The virus is also of interest in having an entirely new kind of insect vector, one with biting mouthparts, namely, a flea-beetle. This is the first record, both of transmission of a virus by this insect and of the insect transmission of a crystalline plant virus.

Electron microscope studies in conjunction with Dr. V. E. Cosslett of the Cavendish Laboratory, and with Dr. R. W. G. Wyckoff in the United States, have also been made [see p. 760 of this issue of *Nature*]. An interesting outcome of this work is that the structure of the crystals of tobacco necrosis virus and turnip yellow mosaic virus has been demonstrated by this means.

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# A NEW MICROSCOPIC PRINCIPLE

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IT is known that the spherical aberration of electron lenses sets a limit to the resolving power of electron microscopes at about 5 A. Suggestions for the correction of objectives have been made; but these are difficult in themselves, and the prospects of improvement are further aggravated by the fact that the resolution limit is proportional to the fourth root of the spherical aberration. Thus an improvement of the resolution by one decimal would require a correction of the objective to four decimals, a practically hopeless task.

The new microscopic principle described below offers a way around this difficulty, as it allows one to dispense altogether with electron objectives. Micrographs are obtained in a two-step process, by electronic analysis, followed by optical synthesis, as in Sir Lawrence Bragg's 'X-ray microscope'. But

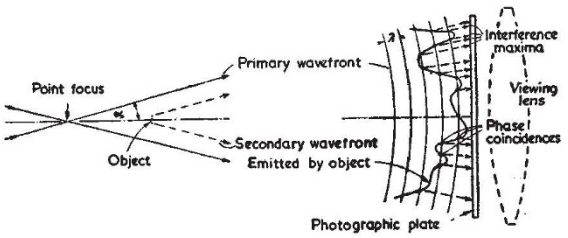


Fig. 1. INTERFERENCE BETWEEN HOMOCENTRIC ILLUMINATING WAVE AND THE SECONDARY WAVE EMITTED BY A SMALL OBJECT

while the 'X-ray microscope' is applicable only in very special cases, where the phases are known beforehand, the new principle provides a complete record of amplitudes *and* phases in one diagram, and is applicable to a very general class of objects.

Fig. 1 is a broad explanation of the principle. The object is illuminated by an electron beam brought to a fine focus, from which it diverges at a semi-angle $\alpha$. Sufficient coherence is assured if the nominal or Gaussian diameter of the focus is less than the resolution limit, $\lambda/2 \sin \alpha$. The physical diameter, determined by diffraction and spherical aberration of the illuminating system, can be much larger. The object is a small distance behind (or in front of) the point focus, followed by a photographic plate at a large multiple of this distance. Thus the arrangement is similar to an electron shadow microscope; but it is used in a range in which the shadow microscope is useless, as it produces images very dissimilar to the original. The object is preferably smaller than the area which is illuminated in the object plane, and it must be mounted on a support which transmits an appreciable part of the primary wave. The photographic record is produced by the interference of the primary wave with the coherent part of the secondary wave emitted by the object. It can be shown that, at least in the outer parts of the diagram, interference maxima will arise very nearly where the phases of the primary and of the secondary wave have coincided, as illustrated in Fig. 1.

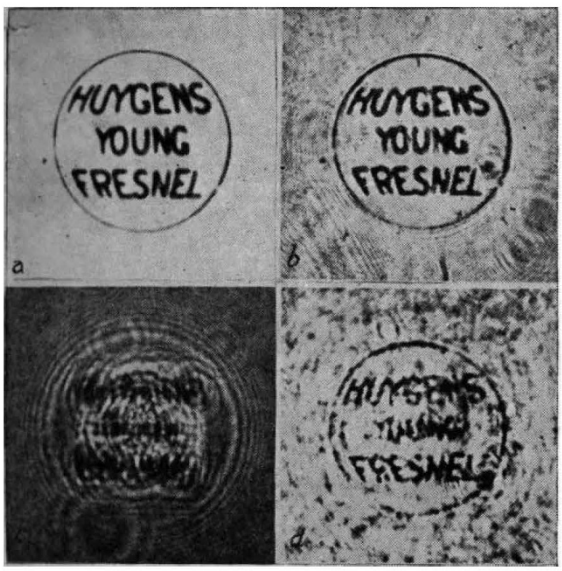


Fig. 2. (*a*) ORIGINAL MICROGRAPH, 1·4 MM. DIAMETER. (*b*) MICROGRAPH, DIRECTLY PHOTOGRAPHED THROUGH THE SAME OPTICAL SYSTEM WHICH IS USED FOR THE RECONSTRUCTION (*d*). AP. 0·04. (*c*) INTERFERENCE DIAGRAM, OBTAINED BY PROJECTING THE MICROGRAPH ON A PHOTOGRAPHIC PLATE WITH A BEAM DIVERGING FROM A POINT FOCUS. THE LETTERS HAVE BECOME ILLEGIBLE BY DIFFRACTION. (*d*) RECONSTRUCTION OF THE ORIGINAL BY OPTICAL SYNTHESIS FROM THE DIAGRAM AT THE LEFT. TO BE COMPARED WITH (*b*). THE LETTERS HAVE AGAIN BECOME LEGIBLE

If this photograph is developed by reversal, or printed, the loci of maximum transmission will indicate the regions in which the primary wave had the same phase as the modified wave, and the variations of the transmission in these loci will be approximately proportional to the intensity of the modified wave. Thus, if one illuminates the photographic record with an optical imitation of the electronic wave, only that part of the primary wave will be strongly transmitted which imitates the modified wave both in phases and in amplitudes. It can be shown that the 'masking' of the regions outside the loci of maximum transmission has only a small distorting effect. One must expect that looking through such a properly processed diagram one will see behind it the original object, as if it were in place.

The principle was tested in an optical model, in which the interference diagram was produced by monochromatic light instead of by electrons. The print was replaced in the apparatus, backed by a viewing lens which admitted about $\sin \alpha = 0{\cdot}04$, and the image formed was observed and ultimately photographed through a microscope. It can be seen in Fig. 2 that the reconstruction, though imperfect, achieves the separation of some letters which could just be separated in direct observation of the object through the same optical system. The resolution is markedly imperfect only in the centre, where the circular frame creates a disturbance. Other imperfections of the reconstruction are chiefly due to defects in the microscope objectives used for the production of the point focus, and for observation.

It is a striking property of these diagrams that they constitute records of three-dimensional as well as of plane objects. One plane after another of extended objects can be observed in the microscope, just as if the object were really in position.

Racking the microscope through and beyond the point focus, one finds a second image of the original object, in central-symmetrical position with respect to the point focus. The explanation is, briefly, that the photographic diagram cannot distinguish positive and negative phase shifts with respect to the primary wave, and this second image corresponds to the same phase shifts as the original, but with reversed sign.

If the principle is applied to electron microscopy, the dimensions in the optical synthetizer ought to be scaled up in the ratio of light waves to electron waves, that is, about 100,000 times. One must provide an illuminating system which is an exact optical imitation of the electronic condenser lens, including its spherical aberration. To avoid scaling-up the diagram, one has to introduce a further lens, with a focal length equal to the distance of the object from the photographic plate in the electronic device, in such a position that the plate appears at infinity when viewed from the optical space of the point focus. Work on the new instrument, which may be called the 'electron interference microscope', will now be taken in hand.

I wish to thank Mr. I. Williams for assistance in the experiments, and Mr. L. J. Davies, director of research of the British Thomson-Houston Company, for permission to publish this note.