or no activity for *L. arabinosus* and may be measured by the chemical method. The microbiological method is undoubtedly more specific for l-tryptophane.

SUMMARY

The amount of l-tryptophane excreted per day by 9 different normal male subjects was determined by a microbiological method with *L. arabinosus* as the test organism. From 12–30 mg per day were excreted as contrasted to an average value of 281 mg per day reported by Albanese and Frankston. A negligible amount of indole in the urine could be demonstrated. Satisfactory values and recoveries of l-tryptophane were obtained at different levels of the test sample.

B. S. SCHWEIGERT
H. E. SÄUBERLICH
C. A. ELVEHJEM

DEPARTMENT OF BIOCHEMISTRY,
COLLEGE OF AGRICULTURE,
UNIVERSITY OF WISCONSIN, MADISON

THE ELECTRON MICROGRAPHY OF CRYSTALLINE PLANT VIRUSES[1]

IT has recently been shown that metal shadow-casting[2] greatly facilitates the electron microscopic study of elementary particles of viruses[3] and of macromolecular substances.[4] Using these techniques we have been examining preparations of purified plant viruses known to form well-defined crystals and we find it possible to record the orderly way in which their particles deposit from solution. Evidently with such a direct method of observation one can approach many fundamental problems of crystal formation that have heretofore been inaccessible to investigation.

Electron micrographs have been made with an RCA Type EMB instrument of ultracentrifugally purified viruses of tomato bushy stunt,[5] tobacco necrosis[6] and southern bean mosaic[7] diseases. Their preparations behave similarly but not in all ways alike, and each has shown ordered arrangements of its particles as seen under the electron microscope. Fig. 1 is a typical photograph of southern bean mosaic virus. The specimen was made by allowing an aqueous suspension of the purified virus to evaporate on the usual collodion-covered screen, which was then shadowed at a five-to-one angle with 8A of gold. The particles seen in this figure, unlike those in such a non-crystalizable substance as limulus hemocyanin[4] are for the most part closely packed in an ordered array. In some places the array is only one layer deep and can be thought of as a two-dimensional crystal, at other points these ordered layers are stacked one above another to produce the three-dimensional regularity that is true crystallinity. Other photographs show the same regularity continuing and becoming more exact as the number of layers of particles increases; well-defined crystal faces and edges have developed on the thicker preparations.

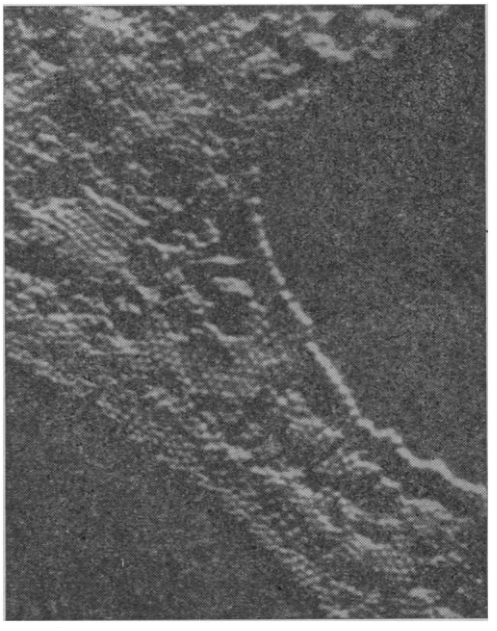

FIG. 1. A shadowed electron micrograph of elementary particles of southern bean mosaic virus showing their ordered arrangement. Magnification is about 58,000 times.

The bushy stunt and tobacco necrosis viruses display similar but not identical regular arrangements of their particles. The bushy stunt virus particles, for instance, have a greater tendency to cover the entire substrate before piling up into three-dimensional aggregates and their two-dimensional patterns have a higher symmetry than that shown by the bean mosaic virus. This accords well with the fact that bean mosaic virus crystals are orthorhombic[7] when developed to ordinary microscopic size, while the bushy stunt virus can form crystals with cubic symmetry.[5] It would appear that in these instances at least we can directly see how the symmetry of a crystal is related to, and determined by, the "shape" of its constituent elementary particles.

[1] From the Department of Physics, from the Virus Laboratory, Department of Epidemiology, School of Public Health, University of Michigan, and from the Department of Animal and Plant Pathology, Rockefeller Institute for Medical Research, Princeton, N. J. Aided in part by a grant from the National Foundation for Infantile Paralysis, Inc.

[2] R. C. Williams and R. W. G. Wyckoff, *Jour. Applied Physics*, 15: 712, 1944.

[3] *Idem, Proc. Soc. Exp. Biol. and Med.*, 58: 265, 1945; SCIENCE, 101, 594, 1945.

[4] R. C. Williams and R. W. G. Wyckoff, *Nature*, in press.

[5] F. C. Bawden and N. W. Pirie, *Brit. Jour. Exp. Path.*, 19: 251, 1938.

[6] W. C. Price and R. W. G. Wyckoff, *Phytopathology*, 29: 83, 1939.

[7] W. C. Price, SCIENCE, 101: 515, 1945.

We are developing further this way of studying the intimate details of crystal structure; results of measurements on our photographs will be published in another place.

W. C. PRICE
ROBLEY C. WILLIAMS
RALPH W. G. WYCKOFF

THE MEASUREMENT OF BLOOD OXYGEN IN MALARIA WITH THE USE OF THE OXIMETER[1]

THE statement that the blood oxygen level falls during the malaria paroxysm has been made frequently; however, there are no detailed studies to support it. Such a study is being pursued with the use of Millikan's oximeter as a part of the malaria research program in progress at the University of Tennessee.

The oximeter is an instrument designed to measure continuously the per cent. of oxygen saturation of the blood hemoglobin. This instrument has been described sufficiently by Millikan,[2] to warrant the omission of any description of its principles and operation here. It has been in use mainly in the aviation altitude indoctrination program, but its use in experimental human physiology in the study of disease and for control of anesthesia in the operating room has just begun.

Patients with neurosyphilis undergoing malaria fever therapy were used. Selected patients were followed with the oximeter throughout their paroxysms, starting about half an hour before the predicted onset of chills and ending with the return of temperature to normal. Control studies were made on these patients before inoculation with malaria. The degree of O_2 saturation as read on the scale of the oximeter was recorded at frequent intervals and the data plotted on a curve. The curve for the control determination and that for the malarial paroxysm could then be compared.

Preliminary studies on ten patients showed some interesting findings. Control studies on the same patient showed that the curves approximated each other very closely, but curves for different patients may vary widely. These variations appeared to bear some relationship to the patient's usual level of activity. The patient who was generally more active dis-

[1] From the Department of Neurology and Psychiatry, University of Tennessee, Memphis, Tennessee.

[2] G. A. Millikan, *Rev. Sci. Instruments*, 13: 434, 1942, and "Oximetry: Continuous Measurement of Blood Oxygen," in "Medical Physics," The Year Book Publishers, 1944.

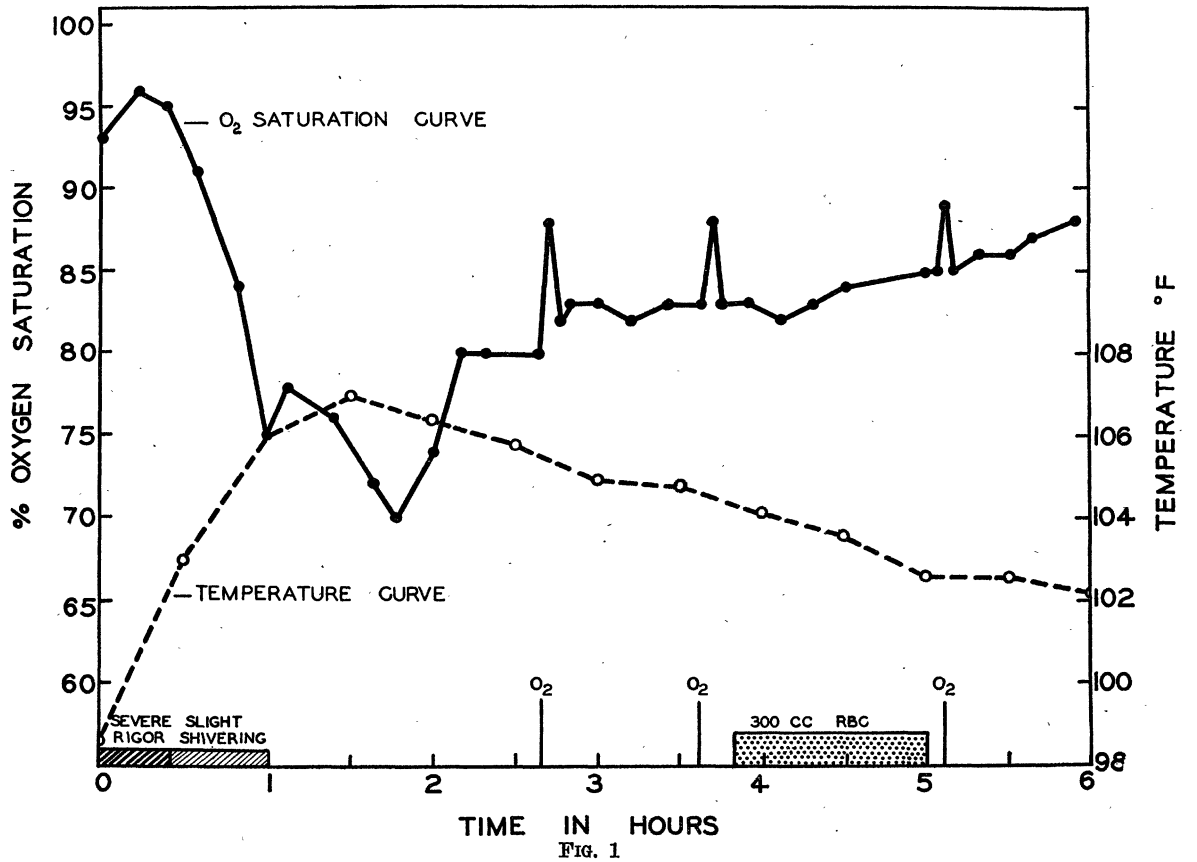

FIG. 1