cal. per quantum) there remains a deficit between the energy required for denaturation and the energy actually available.

The present observations would suggest that the primary step in the bleaching process of visual purple is not a denaturation of the protein carrier but perhaps a photodissociation of the type of the reversible thermal dissociation of ovoverdin. Such a conception would account for the rapidity of regeneration of visual purple under physiological conditions; at the same time, it would help to understand why the visual cycle proceeds at an energy level below that of protein denaturation.

KURT G. STERN
KURT SALOMON

MARINE BIOLOGICAL LABORATORY
WOODS HOLE, MASS.
AND
YALE UNIVERSITY SCHOOL OF MEDICINE
NEW HAVEN, CONN.

THE SEDIMENTATION CONSTANT OF OVOVERDIN

THROUGH the courtesy of Dr. K. G. Stern and Dr. K. Salomon and with their help, preliminary ultracentrifugal studies have been made of rates of molecular sedimentation in ovoverdin solutions prepared from lobster eggs according to the method described in the preceding note.[1] Several points of interest concerning the degree of purity of such solutions and the order of molecular size and homogeneity of the pigmented protein they contain are brought out in this way.

These studies of sedimentation rates are based on series of photographs made with an analytical air-driven ultracentrifuge[2] arranged for measurements according to the original absorption method of Svedberg. Exploratory examination of a solution of the protein in half-saturated ammonium sulfate indicated the presence of a homogeneous protein so light that it should be sedimented from a solvent of lower density. All subsequent measurements were accordingly made, using as starting material a solution freshly dialyzed to remove all but a trace of the ammonium sulfate.

The pigmented solutions of ovoverdin are dark green in color. They show[1] a very strong light absorption in the blue and violet and an appreciable absorption in the yellow; besides this they have the usual protein ultra-violet absorption of wave-lengths below ca. 2800A. Series of sedimentation photographs have been made with blue light and with ultra-violet light shorter than 2700A; simultaneous visual observations were made with yellow light. A photograph with blue light is reproduced in Fig. 1; the second figure is one of the ultra-violet series. In order to have sufficient absorption in the blue, a four millimeter thick cell was used with a solution containing ca 22 milligrams of protein per cc. The sedimentation constant calculated from the diagram of such a solution (Fig. 1) was $s_{20°} = 10.3 \times 10^{-13}$ cm sec^{-1} dynes^{-1}. This solution is far too concentrated to give optimum results with ultra-violet illumination, but a series of photographs made with prolonged exposures showed boundaries yielding the same sedimentation constant—$s_{20°} = 10.4$. It is thus apparent that the blue-absorbing molecules sediment at the same rate as those that absorb in the extreme ultra-violet; from the visual observations it is clear that the substance responsible for the absorption in the yellow comes down at substantially the same rate. These results suggest that the yellow and blue absorptions are due to the same pigment and that this pigment forms part of the protein which presumably is responsible for the ultra-violet boundary.

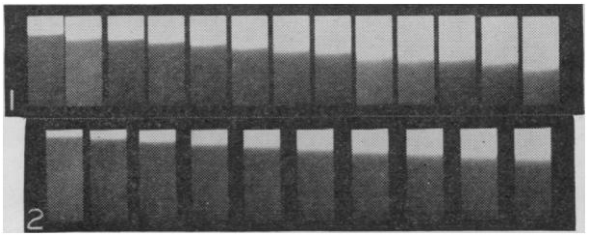

FIG. 1. Sedimentation photographs of ovoverdin using blue light. Source—high pressure mercury arc. Filter—Jena BG 12. Photographic film—Agfa Process. Centrifugal field—ca 90,000 g. Interval between photographs—5 minutes. Exposure—ca ½ second. Fig. 2. A series of sedimentation photographs of ovoverdin, using ultra-violet light. Source—high pressure mercury arc. Filter—chlorine plus bromine cells. Centrifugal field—ca 90,000 g. Interval between photographs—5 minutes. Exposure 1.5 seconds.

Besides this pigmented substance furnishing the boundary with $s_{20°} = 10.3$, these solutions contain an appreciable amount of "unsedimentable" material transparent to visible light but showing a marked ultra-violet absorption. This impurity is not sedimented in the centrifugal fields that have been used. It must therefore be lighter than egg albumin. If it is a protein the viscosity of its solution could be great enough to retard the sedimentation of the large pigmented molecules. This possibility was tested by making sedimentation pictures of the original protein solution after dilution with two parts of water and with eight parts of physiological saline. The slightly higher values of $s_{20°}$ thus obtained—ca 10.8—are probably very near the true sedimentation constant for ovo-

[1] K. G. Stern and K. Salomon, SCIENCE, current issue.
[2] J. Biscoe, E. G. Pickels and R. W. G. Wyckoff, *Jour. Exp. Med.*, 64: 39, 1936; R. W. G. Wyckoff and J. B. Lagsdin, *Rev. Sci. Instr.*, 8: 74, 1937.

verdin. The molecular weight of this protein can not be calculated until its diffusion constant has been determined; but the results of Svedberg[3] indicate that a protein with $s_{20^\circ} = 11$ will probably have a molecular weight of the order of 300,000.

RALPH W. G. WYCKOFF
ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, PRINCETON, N. J.

A BIO-ELECTRIC RECORD OF HUMAN OVULATION[1]

THROUGH the cooperation of a patient in whom a laparotomy was indicated, it has been possible to obtain a continuous graphic record of a voltage difference existing between the symphysis pubis and the vagina for 57 hours. This period included within its limits a predicted time of ovulation based upon day to day observations of the preceding four months.

At noon on July 24, the vagina was negative to the symphysis about ten millivolts. During the next seven hours the vagina gradually became positive until at 7 o'clock it reached thirty millivolts. At 7:05 the recorder was thrown clear off scale, but when the zero point was shifted the voltage record registered between seventy and eighty millivolts. During the next twenty-five minutes this steadily declined until at 7:35 the voltage difference was thirty millivolts, with the vagina still positive. This condition continued until midnight, when the experiment was terminated in order that the patient might obtain a night's rest. At 9:30 A.M., July 25, a laparotomy was done, the ovaries examined and in the left ovary the bright punctate hemorrhage of a recently ruptured follicle was found. Fortunately, this was located at one pole of the ovary. It was resected and immediately fixed in Zenkers.

This observation confirms and extends the studies of Burr, Hill and Allen,[2] Greulich and Hill,[3] and Reboul, Friedgood and Davis.[4] Moreover, it is clear that the use of the Burr-Lane-Nims technique enables one to determine with certainty and accuracy the time of ovulation in an intact human being. A complete account of the observations will be published elsewhere.

H. S. BURR
L. K. MUSSELMAN
DOROTHY S. BARTON
NAOMI B. KELLY

[3] T. Svedberg, *Chem. Rev.*, 20: 81, 1937.

[1] From the Departments of Neuro-Anatomy and Obstetrics and Gynecology, Yale University School of Medicine, aided by grants from the Josiah Macy, Jr., Foundation and the Clinical Fund of the School of Medicine.

[2] H. S. Burr, R. T. Hill and Edgar Allen, *Proc. Soc. Exp. Biol. and Med.*, 33: 109, 1935.

[3] W. W. Greulich and R. T. Hill, personal communication.

[4] J. Reboul, H. B. Friedgood and H. Davis, *Am. Jour. Physiol.*, 119 (2): *Proc. Am. Physiol. Soc.*, 387, 1937.

THE LIFE CYCLE OF MONIEZIA EXPANSA

OVER one hundred species of anoplocephaline cestodes have been described from mammals, birds and reptiles. They are common in herbivorous animals and occur infrequently in man. The development of these tapeworms has been studied repeatedly for the last fifty years. It is noteworthy that, despite their prevalence, wide distribution and economic importance and despite the attempts of numerous investigators to discover the life history, the developmental cycle of these tapeworms has remained an unsolved mystery. The strobilate, sexually mature stage of the cestodes occurs in the intestine, and eggs of the parasite are voided with the feces of the host, but the course of subsequent development and manner by which the final host is reinfected have been entirely unknown. Stunkard[1] has reviewed previous studies on the life cycle of anoplocephaline cestodes and reported experiments, carried on during 1931–1933, which demonstrated that direct infection is impossible and that an intermediate host is necessary for the completion of the life history. The statement was made that the information then available was sufficient to indicate the character of these hosts with much assurance. The bionomic features of the intermediate hosts of this family of cestodes were clearly delineated.

Since 1933 various minute terrestrial invertebrates, chiefly insects, have been used in experiments to determine the life history of the anoplocephaline tapeworms. In the spring of 1936, it was discovered that free living mites would eat the cestode eggs, that the onchospheres would hatch in the intestine and migrate to the body cavity of the mite. In the succeeding months, various tyroglyphid and oribatid mites have been exposed to infection. *Moniezia expansa* is one of the most common and important of these cestodes. Eggs of *M. expansa* were fed to specimens of *Galumna* sp. and the onchospheres recovered in large numbers from the body cavity. Since this mite appeared to be a likely intermediate host, it was used extensively. Thousands of specimens have been exposed during the past year and dissected at various intervals after feeding on *Moniezia* eggs. In this way a series of developmental stages, from the onchosphere to the infective cysticercoid, have been recovered from the body cavity of *Galumna* sp. These results demonstrate the correctness of the conclusions expressed in the paper by Stunkard (1934). The discovery of the life history of *Moniezia expansa* solves the problem of the life cycle among anoplocephaline cestodes. A more complete description of the larval stages will be published elsewhere.

HORACE W. STUNKARD
NEW YORK UNIVERSITY

[1] *Zeitschrift für Parasitenkunde*, 6: pp. 481–507, 1934.