years ago by Kniep and others. Chapters XIII and XIV describe an ingenious self-recording radiograph and a portable photometer which make use of the selenium cell as the light sensitive element.

The question of the influence of $CO_2$-concentration on the rate of photosynthesis has received much attention during the past ten years. It is of particular importance on account of its bearing on Blackman's theory of limiting factors. That the curve of photosynthetic activity with varying concentration of $CO_2$ and constant light intensity exhibits no sharp turn but is rather approximately a logarithmic one was indicated by the results of Boysen-Jensen (1917), Willstaetter (1918), Warburg (1919), Harder (1921). Bose also concludes: "My results show that the top of the photosynthetic curve rounds off gradually after the turning-point, and is never abruptly horizontal . . ." Only one light intensity was used; had similar experiments been carried out with a variety of light intensities they would have constituted a valuable test of Harder's conception of limiting factors. An attempt is also made to determine the oxygen-carbohydrate factor, a ratio between the weight of oxygen emitted and that of carbohydrate elaborated during photosynthesis. On the basis of the chemical equation commonly assumed to represent the photosynthetic reaction: $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$ this ratio would be $\frac{C_6H_{12}O_6}{6O_2} = \frac{180}{192} = 0.9375$. The author measured the gas emitted and determined the increase in weight during a definite period of photosynthetic activity. He comes to the conclusion that the oxygen-carbohydrate factor is 0.8906 or 5 per cent. less than the theoretical value. This is called the normal value. In specimens which previously had been exposed to strong light the factor was 0.91, in those exposed to semi-darkness 0.87. The explanation for these discrepancies is sought in the possibility that other carbohydrates besides those having a molecular weight of 180 are elaborated. Apparently the fact, clearly established by Kniep, was lost sight of: that the gas evolved in photosynthesis is not pure oxygen, the composition varying with the rate of gas evolution. Analyses of the gas were not made nor were precautions taken to avoid admixture of other gases. The low value of the $\frac{\text{carbohydrate}}{\text{oxygen}}$ ratio is in all probability due to the fact that the gas collected was not pure oxygen. Furthermore, under conditions of high light intensity (more active photosynthesis) the proportion of oxygen in the emitted gas is high, which accounts for the relatively high value of the carbohydrate-oxygen factor found; while under low light intensity the proportion of oxygen is low, which would result in a correspondingly low factor by the methods employed.

It is undoubtedly true that physiology is more than applied physics and chemistry; yet in endeavoring to ascribe to every effect a discernible cause in a quantitative as well as qualitative sense, it is doubtful whether physiology can find, for the present, more valuable methods and conceptions than are offered by physics and chemistry. This is especially true in the subject of photosynthesis, for which the exact sciences have made available most valuable information during the past few years, and it is only through the application and elaboration of these conceptions that we can hope for a true physiology of photosynthesis.

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## LABORATORY APPARATUS AND METHODS

### INSTANTANEOUS PHOTOMICROGRAPHY OF THE SKIN CAPILLARIES IN THE LIVING HUMAN BODY

LOMBARD,[1] in 1911, showed that certain capillaries in the human body could be rendered visible under the microscope by adequate illumination. Dr. Mueller and his pupils have extended the usefulness of this method in clinical medicine. Professor Krogh,[2] of the University of Copenhagen, and his colleagues have made very elaborate studies on the anatomy and physiology of capillary circulation. For several years past, Drs. G. E. Brown[3] and H. Z. Giffin[4] and others, of the Medical Research Laboratories of the Mayo Clinic, have been making extensive quantitative clinical studies of the capillaries, as to sizes and blood circulation, both in normal and disease conditions.

In the microscopic study of the physiology of capillaries, the general method of procedure has been to observe visually by the aid of the microscope the changes taking place and the reactions to various experimental procedures. However, no documentary evidence of these observations by means of photographic records has been, in general, possible and, so far as we know, no such documentary evidence exists in the various studies on the capillaries of the living human body. Krogh[5] and others have suc-

[1] Lombard, *American Journal of Physiology*, Vol. xxix, 335, 1911–12.

[2] Krogh, "The Anatomy and Physiology of the Capillaries," New Haven, 1922.

[3] Brown, *American Annals of Clinical Medicine*, Vol. 1, 69, 1922.

[4] Brown and Giffin, *American Journal of Medical Sciences*, Vol. 166, 489, 1923.

[5] Krogh and Rehberg, *American Journal of Physiology*, Vol. lxviii, 153, 1924.

ceeded in obtaining with considerable difficulty photomicrographic records of the capillaries and the circulation in transparent tissues of *Rana temporaria* "at rates varying from 20 photographs per second downwards." Obviously, methods and procedures which would be applicable to the study of the capillaries in transparent tissues of frogs, in which transmitted light could be used, would be of little or no service in obtaining photomicrographs of the capillaries of the human body in from one tenth to one one-hundredth second. For the results obtained in photomicrographing capillaries at the nail-fold, for example, must be dependent on the amount of light which penetrates into the tissues, the portion thereof which is reflected by the capillaries (that is, the contained blood) and which then, in turn, traverses its way through the tissues to the microscope.

As is well known, but little light is needed to make the capillaries microscopically visible to the eye. The problem from the photographic standpoint, however, is much more difficult, due chiefly to the following: (1) inability to get sufficient illumination returned to the plate or film to enable photomicrographs to be obtained in a fraction of a second; (2) with longer exposures, of the order of a few seconds, the difficulty of preventing mechanical movements of the hand or finger, or again of the apparatus used, and (3) should such movements as have been mentioned be eliminated, the impossibility of prevention of slight rhythmic movements due to the pulsations of the heart.

Certain preliminary experiments demonstrated to our satisfaction the uselessness of endeavoring to overcome the difficulties mentioned in (2) and (3), and that success in instantaneous photomicrography of the capillaries in the tissues at the nail-fold would result only through the use of very intense external illumination, so filtered as to remove heat and certain shorter wavelengths of radiation, and directed at such an angle as to throw the light reflected by the surface of the skin out of the direct path of the light reflected by the capillaries and transmitted to the photographic plate or film. Our procedure has been to use as a source of light a 5 ampere direct current arc-lamp, with which to make preliminary visual observations, and, when photographing, to throw suitable resistances in parallel with the fixed resistance for an instant only, permitting 30 to 50 amperes to flow through the arc-lamp. In this manner, both with and without suitable glass and liquid filters, we have been able to obtain satisfactory photomicrographs varying in magnification from 100 to 10 in from one tenth to one one-hundredth second. The contrast has been excellent, the mechanical and rhythmic movements previously mentioned wholly eliminated, and the possibility of an "at-will" photographic record of capillary changes assured. We have also succeeded in making use of an ordinary kodak film, and in taking a series of photomicrographs as desired, approximating a cinematographic record as closely as would ordinarily be desired or of likely service. Further experiments are being carried out on the construction of simple but suitable apparatus for enabling long series of permanent records of capillaries to be taken and kept for measurement and the tabulation of data.

We are informed that various persons have, at different times, made attempts to obtain instantaneous photomicrographs of the capillaries in the living human body, but, in so far as we know, none of these attempts have been successful. Mr. Earl Irish, working in conjunction with Dr. Brown, of this clinic, succeeded about two years ago in getting two fairly good photomicrographs, but the times of exposure were too long and there were evidences of movement. Through the use of the simple procedure we have outlined, practically every photograph is satisfactory and usable for measurements.

We believe that these photomicrographs which we have been able to obtain during the past few weeks are the first photographic records on skin capillaries in the living human body obtained by methods which permit of photographing at will, under normal conditions—for example, without ballooning through the use of a turniquet, and so forth—with good contrast, in any magnification desired, and in from one tenth to one hundredth second, thus ensuring no movements and therefore giving reliability to the data obtained from the measurements of the capillaries.

A reproduction of an "untouched" print made from an original plate in which the magnification is 100 and the time of exposure one tenth second, is enclosed, but I feel that it can not be reproduced to advantage on the paper used in Science.

The problem of accurate quantitative determinations of the caliber of the capillary loops is wrapped up very intimately with the problem of capillary permeability. It is hoped that these studies will lend additional assistance to the solution of the problems of clinical medicine.

A more detailed account of these experiments and others now in progress will be made later through the channels of medical literature.

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