COMPARATIVE STUDIES ON RESPIRATION.

VII. RESPIRATION AND ANTAGONISM.

INTRODUCTORY NOTE.

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The relation of antagonism to such fundamental life processes as respiration and photosynthesis has received scant attention. The writer began studies on this subject some years ago, but owing to other interests the investigations did not progress beyond the preliminary stage. It seemed desirable that they should be carried forward, and this was facilitated by the development of new methods of measuring respiration and photosynthesis.¹

A series of studies has recently been commenced in which these methods have been employed. Care was taken to make frequent measurements, as earlier work had shown this to be important. The fact that the rate of respiration could be determined as often as once every 3 minutes made it possible to obtain satisfactory time curves.

The plan of these investigations involves a comparative study of the antagonistic effects of salts on different kinds of organisms under precisely the same conditions. In this way it is hoped that a sound basis for the formulation of general principles may be provided.

It may be of interest to mention certain improvements in technique. When a reagent is employed which has a buffer effect it is desirable to have the same buffer action during the measurement of normal respiration as during exposure to the reagent. This may be accom-


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plished by introducing the reagent into the apparatus\textsuperscript{2} in a separate tube, having an outlet which is flush with the inside of the stopper. When the time comes to bring the reagent into contact with the organism the tube is inverted and the current of air carries the reagent over into the tube containing the organism. In order that the height of the liquid in the latter tube may not be unduly raised it may be provided at the bottom with rubber tubing, into which, after thorough mixing, some of the liquid may be received and clamped off.

If the reagent is volatile it is necessary to substitute for it (during the measurement of normal respiration) a non-volatile liquid having the same buffer action.\textsuperscript{3} The volatile reagent may be placed in the rubber tubing, attached to the tube containing the organisms, and clamped off until the time comes to bring it into contact with the organisms. The clamp is then opened and, after thorough mixing, the height of the liquid is adjusted as described above.

Since respiration is affected by acidity and alkalinity it is desirable to add an indicator to the liquid containing the organisms in order to follow its reaction. The color of this indicator may be affected by the color of the organism or by that of the medium, but in most cases it affords useful information regarding changes in the reaction of the liquid.

There have been few previous investigations on this subject. Warburg\textsuperscript{4} found that the consumption of oxygen by fertilized eggs of the sea urchin (\textit{Strongylocentrotus}) fell off when the eggs were transferred from sea water to a solution of NaCl (isotonic with sea water). This is explained by the fact, previously discovered by Loeb,\textsuperscript{5} that NaCl causes cytolysis of the eggs. Loeb had found that this injury could be prevented by the addition of a trace of NaCN. Warburg accordingly added NaCN to the solution of NaCl and found that the amount of oxygen consumed was five times the normal. Addition of CaCl\textsubscript{2} brought it back to the normal amount.

\textsuperscript{2} For a description of this see Osterhout, W. J. V., \textit{J. Gen. Physiol.}, 1918-19, i, 17.
\textsuperscript{3} See Osterhout, W. J. V., \textit{J. Biol. Chem.}, 1918, xxxv, 237.
\textsuperscript{5} Loeb, J., Die chemische Entwicklungserregung des tierischen Eies, Berlin, 1909.
Loeb and Wasteneys pointed out that Warburg's interpretation of his results is of doubtful value, owing to complications introduced by the addition of NaCN. In experiments on the fertilized egg of Arbacia Loeb and Wasteneys found that there was no increase in the consumption of oxygen in a solution of NaCl (without NaCN) even when due allowance was made for the percentage of eggs killed by the action of the solution. In NaCl + KCl the eggs consumed approximately the normal amount of oxygen and the addition of Ca was practically without effect.

Meyerhof repeated Warburg's experiments on Strongylocentrotus, using a solution of NaCl (without NaCN) and making determinations after 12, 15, or 20 minutes, during which short periods little injury occurs. He found that the consumption of oxygen was from two to four times as great as in sea water. The addition of CaCl₂ reduced the consumption of oxygen to the normal. The addition of KCl to NaCl had practically no effect.

Similar experiments have apparently not been performed upon plants.

The investigations thus far completed in the writer's laboratory show a much closer agreement with the results of Loeb and Wasteneys in regard to NaCl than with those of Warburg and Meyerhof. They also show pronounced antagonism between such substances as NaCl and CaCl₂ in their effect on respiration.

Reports of some of these investigations will appear in the near future.

7 The experiment lasted an hour, during which time the solution has little injurious action.
8 Meyerhof, O., Biochem. Z., 1911, xxxiii, 291.