Studies showing the effects of the osmotic pressure of the medium upon the organism have been numerous and various. Little work, however, has been done upon the relation of the production of carbon dioxide as affected by varying the osmotic pressure of the medium in which the organism lives.

Smith\(^1\) reports that stems of *Tropaeolum*, stems and roots of bean seedlings, and leaves of snowdrops, after deprivation of one-third to one-half of their total water by drying, respired more than normal plants. No increase in the respiration was observed on partly drying young stems of peony and asparagus.

Palladin and Sheloumova\(^2\) observed that potato tubers, when allowed to lose water by drying in the air or by immersion in a 10 per cent solution of sodium chloride, in general showed a decrease in the amount of carbon dioxide produced.

Bailey and Gurjar\(^3\) have investigated the respiration of seeds as related to the amount of water present. In general it is shown the respiration falls off as the moisture diminishes.

Warburg\(^4\) stated that hypertonic solutions may increase the consumption of oxygen by fertilized eggs of the sea urchin as much as three or four times. Loeb and Wasteneys\(^5\) repeated these experi-

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ments using a different species (*Strongylocentrotus purpuratus*) and found no increase when sufficient NaCl was added to increase the specific gravity of the sea water by about 50 per cent. They found an increase in the case of unfertilized eggs (as did Warburg) but they attributed this to the fact that the hypertonic solution causes the formation of a membrane. Unfertilized eggs which had already formed membranes (as the result of treatment with butyric acid) showed no increase in hypertonic solutions. Measurements by the writer of the specific gravity of the solution described by Loeb and Wasteneys showed it to be about 1.036, while that of the most concentrated solution used by the writer was much above this.

Using the method of measuring respiration described by Osterhout, the writer undertook to measure the production of carbon dioxide while the osmotic pressure of the medium was changed sufficiently to be highly hypertonic on the one hand and quite hypotonic on the other. The marine alga *Laminaria agardhii* was used as the basis of most of the work. The results with *Ulva lactuca* were quite similar to those with *Laminaria*.

It was found that the carbonates of sea water interfered with the measurement of the carbon dioxide produced, and to overcome this difficulty the chamber containing the *Laminaria* was lined with filter paper dipped in artificial sea water (van't Hoff's solution, containing no carbonates). No other liquid was added but the chamber was so small that a very slight amount of evaporation sufficed to saturate the air. The change thereby produced in the concentration of the solution in the thallus was negligible and the cells may be regarded as bathed in a solution of constant concentration during the experiment. Uniform normal respiration was also obtained when the *Laminaria* was immersed in artificial sea water or placed in the respiration chamber without the addition of liquid or moistened filter paper.

The pieces of *Laminaria* were selected from fresh material as nearly uniform in size as possible and placed in the container. The normal rate of respiration was then obtained for each piece of tissue before it was treated. The pieces were then removed and exposed to the hypertonic or hypotonic solution for 5 minutes, at the end of

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which time they were placed in the chamber (with a little of the same liquid as that with which they had been treated) and the rate of respiration was then measured at intervals of 10 to 20 minutes, until the expiration of 60 minutes.

The concentrated solutions of sea water were obtained by slow evaporation of normal sea water both with and without the use of heat.

No difference was found in the results they produced when of the same concentration. Artificial sea water (van't Hoff's solution, without the carbonates) in high concentration affected respiration in the same manner as ordinary concentrated sea water. The specific gravity of the sea water was measured by means of a Westphal balance and

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**Fig. 1.** Curves showing the rate of respiration of *Laminaria* during exposure to sea water of various specific gravities and freezing point depressions. Δ for Woods Hole sea water is normally -1.81 and the specific gravity 1.024. The ordinates represent the rate of production of CO₂ expressed as per cent of the normal. The normal rate represents a change in pH from 7.78 to 7.36 in from 1.5 to 2 minutes. The abscissae represent time in minutes. Average of 3 or more experiments: probable error of the mean less than 10 per cent of the mean.
the depression of the freezing point was approximately determined by means of a Beckmann apparatus. The temperature of these experiments was $18^\circ \pm 2^\circ C$.

Fig. 1 shows quite clearly that in higher concentrations, e.g. specific gravity 1.130 ($\Delta = -9.37$) there was always a decrease in the amount of carbon dioxide given off. It is also shown that with hypotonic solutions the decrease in respiration is not so pronounced.

![Fig. 1: Graph showing the rate of respiration of Laminaria in relation to the specific gravity and freezing point depression of sea water. The upper curve shows per cent of respiration at end of 10 minutes for all concentrations and dilutions. The lower curve shows the same at end of 40 minutes. The point at the intersection of the curves represents normal sea water. These curves are constructed from the same data as the curves in Fig. 1. The ordinates represent rate of production of CO$_2$ expressed as per cent of the normal. Abscissae represent specific gravity; under each of the numbers denoting specific gravity is noted the corresponding freezing point depression.](image)

Fig. 2 shows the relation between the specific gravity of the solution and the respiration to be almost a linear function in the case of hypertonic solutions. In the case of hypotonic solutions it is not so simple.

Experiments of a similar nature were carried out on wheat seedlings in which hypertonic solutions alone were used. Hypertonic solutions,
of the same specific gravity as sea water (specific gravity 1.024), of sodium chloride and calcium chloride were tried; also a mixture of sodium chloride and calcium chloride in the molecular proportion of 50:1. The results were all similar to those produced by the use of hypertonic sea water on *Laminaria* in that there was always a fall in the rate of respiration.

**SUMMARY.**

1. In highly hypertonic solutions of sea water the rate of respiration of *Laminaria agardhii* is rapidly reduced.

2. In highly hypotonic solutions the rate of respiration of *Laminaria agardhii* is reduced somewhat less rapidly than in the case of hypertonic solutions.

3. Hypertonic solutions of NaCl, CaCl₂, and of mixtures of NaCl, and CaCl₂ in the proportion of 50:1, all caused a decrease in the rate of respiration of wheat seedlings.