COMPARATIVE STUDIES ON RESPIRATION.

XVII. DECREASED RESPIRATION AND RECOVERY.

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In a previous paper the writer\(^1\) has shown that exposure to hypotonic or hypertonic solutions may greatly lower the production of carbon dioxide by \textit{Laminaria agardhii}. The object of the present investigation was to determine whether the respiration would become normal when the plant was replaced in sea water. The work was done at Woods Hole, where material could be obtained under the most favorable conditions.

The normal rate of respiration was determined (in the manner previously described) and the tissue was exposed to the hypertonic or hypotonic solution for a definite time; it was then removed and its respiration was measured.\(^2\) The piece of tissue was then replaced in running sea water. At varying intervals it was removed and the rate of respiration was determined. As in the previous investigation\(^1\) these determinations were made in van't Hoff’s solution in order to avoid the buffer effect of the sea water.

Fig. 1 shows that in strongly hypertonic sea water respiration steadily decreases and that the degree of recovery depends on the length of the exposure. After an exposure of five minutes recovery is practically complete: as the period of exposure is lengthened recovery is less and less complete and when the exposure amounts to 20 minutes there is no recovery whatever.

It is evident that the upper curves dip slightly after the tissues are returned to normal sea water. This is not seen in the experiments with hypotonic solutions and isotonic sodium chloride and may

\(^1\) Inman, O. L., \textit{J. Gen. Physiol.}, 1921, iii, 533.

\(^2\) The measurement of respiration was always made with the tissues in the dark.
perhaps be explained as a purely mechanical disturbance due to the
great differences in osmotic pressure as the result of which the
tissue must remain about 30 minutes in normal sea water before the
reajustment is complete.

Fig. 2 shows that the effects of strongly hypotonic sea water are
similar to those of strongly hypertonic, except that the lowering of
respiration is not so pronounced. Here also we observe all degrees
of recovery depending on the length of exposure to the solution.

![Diagram](https://example.com/diagram.png)

**Fig. 1.** Curves showing rate of respiration of *Laminaria* (expressed as per cent
of the normal). The normal rate represents a change from pH 7.78 to 7.36 in
from $1\frac{1}{2}$ minutes to 2 minutes, depending upon the amount of material used.
The solid lines show rate of respiration while tissue was exposed to hypertonic
sea water (sp. gr. 1.130, $\Delta = -9.37$ approximately). The dotted lines show
stages of recovery after the tissue was put back in normal sea water. Each curve
represents a typical experiment. The figure attached to each recovery curve
denotes the time (in minutes) of exposure to the solution of hypertonic sea water;
thus the uppermost curve represents recovery, after an exposure of 5 minutes.

The question naturally arises as to what happens when these pieces
of tissue are kept longer than $20$ hours in running sea water. This
was carefully investigated and it was found that every piece of tissue
which had been exposed to hypertonic or hypotonic sea water died
and disintegrated much sooner in running sea water than the normal
piece of tissue kept in the same vessel and treated in the same manner
except that it was not exposed to hypertonic or hypotonic solutions.
Pieces of tissue that showed complete recovery were found to live longest, as expected, but none of these remained normal more than seven days while the untreated showed a normal rate of respiration after eighteen days. Those pieces that showed partial recovery were marked by a fall in the rate, usually at the end of three days, but in a few cases not until the end of five days. Where there was no recovery the pieces turned green and soon disintegrated.

A series of experiments was made in which pieces of *Laminaria* were placed in isotonic sodium chloride (0.52 M for Woods Hole sea water) and the respiration measured at the end of an hour. The pieces were then returned to running sea water and at intervals shown by the points on dotted lines of Fig. 3, they were removed and the rate of respiration determined.

In this case some pieces of tissue were more affected than others by the same length of exposure (due to the thickness of the fronds, the temperature of the experiment, etc.), and it is noticeable that the greater the lowering of the respiration the less complete the recovery. Here also it was found that the treated pieces of tissue lived but a short time in running sea water as compared with the normal pieces.
It is therefore evident that in all these experiments recovery may be incomplete and even where the tissue is kept for days under the most favorable circumstances there is no tendency in these cases for the recovery to complete itself. This offers a striking parallel to the experiments recently described by Osterhout in which all degrees of recovery (depending upon the length of exposure) were observed when *Laminaria* was placed for a time in 0.52 M sodium chloride (and in other solutions) and then replaced in sea water. In this case electrical conductivity was used as a criterion of recovery.

![Diagram showing rate of respiration of *Laminaria*](https://example.com/diagram.png)

**Fig. 3.** Curves showing rate of respiration of *Laminaria* (expressed as per cent of the normal). The normal rate represents a change from pH 7.78 to 7.36 in from 1½ to 2 minutes, depending upon the amount of material used. The solid lines show rate of respiration during one hour of exposure to isotonic sodium chloride (0.52 M for Woods Hole sea water). The dotted lines show stages of recovery after the tissue was put back in normal sea water. Each curve represents a typical experiment.

It is possible that when recovery is incomplete none of the cells are killed but that their respiration is permanently decreased. It is also possible that some cells continue to respire normally while others are killed and that it is the death of these cells which prevents complete recovery. This question must remain for future investigation.

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4 Unpublished experiments by Osterhout on the electrical conductivity of *Laminaria* show incomplete recovery after exposure to hypo- and hypertonic solutions.