THE PENETRATION OF CATIONS INTO LIVING CELLS.

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According to some investigators the living cell is impermeable to salts, while according to others it is permeable to anions but not to cations. The object of the present investigation is to throw some light on the problem by making direct determinations of the penetrating substances.

The literature of the permeability of protoplasm to salts has been summarized by Brooks and will not be discussed here. Attention may, however, be called to the fact that satisfactory direct methods of study have been lacking. The importance of obtaining direct evidence of the penetration of substances into the protoplasm cannot be overestimated.

The demonstration of direct penetration has been very difficult because individual cells are usually so small that their contents cannot be analyzed. Meyer, Hansen, Wodehouse, and Crozier have examined the cell contents of Valonia for evidence of penetration of salts from sea water. In this case the cell sap can be obtained without contamination and in sufficient quantities for examination.

By employing a large form of Nitella the writer was able to investigate the penetration of several cations from balanced and from unbalanced solutions. This species of Nitella is especially favorable because of the length of the (multinucleate) cells (5 inches is not unusual), and the amount of cell sap which can be expressed from a single cell.

The cells were placed in the solutions for various lengths of time. When they were taken out they were thoroughly rinsed in running tap water, dried with filter paper and pierced with a fine pointed capillary pipette, which collected the cell sap in a very satisfactory manner. This was tested by means of the spectroscope.

The normal cell contained Na, Ca, and Cl; for this reason Na and Ca were not used in making up the test solutions.

The cations used were Li, Cs, and Sr. In order to avoid plasmolysis hypotonic solutions were employed.

In order to make sure that the tests obtained were not due to small quantities of the solution adhering to the outside of the cell, cells were placed for half an hour or longer in each solution, taken out, washed in running water, and tested in the usual manner. The test was in all cases negative, showing that the method as ordinarily used excludes errors due to contamination.

When *Nitella* was placed in 0.05 M LiCl, penetration of Li could be demonstrated in 24 hours. At this concentration the salt was not toxic. The cells remained in good condition for 4 days (after which the experiment was discontinued). Other plants which had been placed in 0.025 M LiCl gave a faint test for Li in 48 hours and were found to be in excellent condition at the end of 13 days.

In a balanced solution of Li (containing 10 parts 0.04 M LiCl, 9 parts tap water, and 1 part sea water) the cell sap gave a good test in 48 hours and cells were found to be in excellent condition at the end of 16 days.

Other cells were placed in 0.05 M CsCl and gave a good test in 24 hours. These were under observation for 6 days, during which time they remained in good condition.

In a balanced solution containing 10 parts 0.05 M CsCl, 9 parts tap water, and 1 part sea water, the cell sap gave a good test for Cs in 3 days, and the cells remained in good condition for 4 days (after which the experiment was discontinued).

In SrCl₂ (0.075 M) *Nitella* remained alive for 20 days, and there was a slow penetration requiring 3 days or more to give a good test. The

*The solutions were approximately neutral. The temperature did not vary much from 19°C.*
penetration of Sr from a balanced solution containing 10 parts SrCl₂ (0.075 M), 9 parts tap water, and 1 part sea water, was still slower. These experiments demonstrate that Li, Cs, and Sr penetrate into the interior of the living cell and that this occurs more rapidly in an unbalanced than in a balanced solution. That they may penetrate in the form of ions is evident from the fact that in salts of these metals the electrical conductivity of the living cell is such as to show that the cations Li, Cs, and Sr readily penetrate the protoplasm. Since this occurs at the very start of the experiment, before any appreciable injury has occurred, it is evident that the cell in its normal condition is permeable to these cations.

SUMMARY.

Direct tests of the cell sap of Nitella show that the protoplasm is normally permeable to Li, Cs, and Sr, and that penetration is more rapid in an unbalanced than in a balanced solution.

† These results were obtained by the method described by Osterhout (Osterhout, W. J. V., J. Gen. Physiol., 1921–22, iv, 275).