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CONTRIBUTIONS TO THE PHYSICAL-THERMICAL ANALYSIS OF THE MECHANISM OF REACTOR PRESSURE H. PLANTS

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CONTRIBUTIONS TO THE PHYSICAL-CHEMICAL ANALYSIS OF THE MECHANISM OF TURGOR PRESSURE IN PLANTS

(Following is the translation of an article by Hans Pfeiffer (Bremen), published in the German language periodical Protoplasma, Vol. 2, 1927, pages 206-07, 222-24, 233-34. Translation performed by Constance L. Lust.)

Pages 206-207

Statement of the Problem: We have to include the morphological and physical chemical character of the differentiating abscission tissues in the abscission processes which leads to the separation of plant-organs. The mechanism of turgor pressure may be intimately involved in the abscission phenomena. Wiesner described turgor pressure along with Benecke (3,p.456f), for it was largely unknown previously. This frequent occurrance is dependent on energy. This condition, the above-mentioned author mentioned only barely. Perhaps the phenomenon of blossom-release is so simple that the process is just not extensively discussed in the current literature. For this reason it is hoped that this discussion will lead to other fruitful investigations. I showed that according to our present knowledge the process extends far beyond that described by Benecke. Approaching the problem from the colloidal point of view a hypothesis of the process may be forthcoming. Despite the fact that many details are still lacking, I believe the results should be published.

Concepts and General Methodology: The energy needed for separation of tissue-elements arises from the turgor mechanism through the turgor pressure. This pressure may be high or low. The physical-chemical aspects of the concepts "turgor-elevation" and "turgor-decrease", as well as the phenomenon of retention of relatively large quantities of water by certain tissues, has not been adequately investigated for plants. Because of the limited space available this aspect shall not be dealt with in any detail. The most important authors in this area will be listed: I.M.Janse (Ber. Deutsch. Bot. Ges. 1886, 4, 277), O.Penzig (Atti Soc. ligust. sc. nat. et geogr. 1895, 6, 18), J. Furlani (Osterr. bot. Zeitschr. 1906, 56, 400), O.Richter (54, 55), Br.Kubart (Sitz-Ber. Wiener Akad. Wiss., math.-nat. Kl., Abt.I, 1906, 115, 1498) E.Loewi (ibid. 1907, 116, 985), H. Fitting (Pringsheims Jahrb. 1911, 49, 245), F.C.v.Faber (Ann. jard. bot. Buitenzorg 1912. Ser. II, 11, 258), E. Hannig (Zeitschr. f. Bot. 1913, 5, 417), F. W. Neger and J. Fuchs (Pringsheims Jahrb. 1915, 55, 609), H. Zimmermann (Zeitschr. f. Pflanzenkrankh. 1916, 26, 280, E. Kuster (Ber. Deutsch. Bot. Ges. 1916, 34, 187) u.v.a. and others. As far as work with algae is concerned the work of Beneckes (3, a.a.O.) must be considered of prime importance. However, the mechanism itself could hardly have been critically studied at that time. Even the question concerning the phenomenon of water accumulation was barely touched (mentioned). In the zoological field an answer to this water retention phenomenon has been sought more intensly. M. H. Fischer was a most thorough investigator in this field

(16, p. 149f). Since the complicating factors of blood vessels and the lymphatic system are absent in plants (but are found in zoological forms; it was hoped that a relatively simple schema for the elevation of turgor pressure would be found.

Pages 222-223. Conclusions from the Methods

1) With a certain concentration of the narcotics chloralhydrate, ethylether, or chloroform a definite speeding-up of the abscission reaction occurs in the male blossoms of Vallisneria spiralis.

2) The effects of the narcotic alone are not adequate to cause separation. However, a temporary influence os the reagent does cause some of the effects mentioned. This is assuming that enough reagent was provided to stimulate the reaction.

3) Even though low concentrations of the narcotic cause a faster abscission of blossoms, a higher concentration causes a definite inhibition in the reaction. This may be seen for 14 days and longer (until termination of the experiment). The cells finally die.

4) The effect of the narcotic on blossom abscission is in part directly dependent on the test solution. It is interesting that the best results are obtained between pH 3.7 and 4.8(isoelectric point of most cell proteins?) In strongly acidic media and strongly basic solutions, and to a lesser degree in weakly-acidic media, inhibitory effects appear that do not necessarily lead to necrosis and death processes.

5) Besides narcotics no other permeability inhibitors and turgor-pressure elevating factors have been recognized, which give similarly good results. From this is was concluded that other factors influence the combined vegetative and developmental processes of cells more than the effects of narcotics. The simple mechanism of turgor pressure elevations is largely rearranged by these effects.

B. Conclusions about the physical-chemical conditions of the abscission cells.

6) It may be assumed the the separation process of the male blossoms of Vallisneria spiralis is initiated by means of an increase in the turgor pressure of the abscission cells. This change in pressure is dependent on a measurable increase of the osmotic pressure of the water phase of the protoplasm.

7) A permeability decrease is associated with the increase in osmotic pressure and increased affinity for the solution. The change in permeability is a basic factor to be considered.

8) The variation of the dynamic equilibrium is associated primarily with the abscission cells. Other, neighboring, tissue complexes remain astonishingly unaffected.

9) The abscission cells already exhibit an altered physical-chemical picture before separation. This was implied from the accumulation of building materials in this area. The catabolism of these materials presumably takes place in the physical-chemical-altered abscission-cells. The products of anaerobic metabolism may be able to alter the dynamic equilibrium in these tissues.

10) Maximum turgor pressure of the abscission cells is the point at which the increasing concentration of osmotic substances causing increased turgor pressure is stronger than osmotic pressure of the internal contents of separation cells. The maximum turgor pressure is, of course, reached prior to abscission.

Pages 233-234
Summary of the two methods and the working-hypothesis of increased turgor pressure

In summary of the discussions and investigations of the second main chapter the following topics are mentioned (see also the conclusion of the first main chapter p. 222):

If the mechanism of turgor in reference to abscission in plants is defined in terms of the energy dependent turgor pressure, actually two different abscission mechanisms with different origins and varying processes of separation are considered. A common feature for both is that of a strong tendency for the abscission cells to "round off". Another mechanism (Benecke) is concerned with turgor pressure drop (also called depression mechanism). Another mechanism involves increased turgor pressure (ascension mechanism). Benecke investigated the depression mechanism very thoroughly, however not adequately in terms of the current situation. Nevertheless, present research on the depression mechanism still draw heavily on his basic findings as well as his techniques, and generally serves as a basis for current work.

The apparently much more widely accepted ascension mechanism (except in most turgor-pressure-difference caused abscission of higher plants) was investigated in the abscission tissues of Vallisneria spiralis L. during separation of the male blossom. (According to other ephydrogemous plants the ascension mechanism is also important in Helodea iowensis Wylie and Lagarosiphon muscoides Harv. Many other variables must still be investigated more thoroughly to definitely establish which is in effect.) The following mechanism of separation has evolved as a working hypothesis. After a definite period of inactivity (cytoplasmic irritation; other factors in metabolism) the metabolism of the cell is somehow disturbed. This in turn is expressed as an alteration in the normal ionic equilibrium as well as the usual H^+/OH ratio of the cells. The change of the normal ionic equilibrium in the abscission cells leads to a situation which is no longer regulated. The adverse regulations of the ionic conditions result in a permeability decrease and certain swelling processes, occasionally even a regular retention of osmotic substances. This results in a situation where the increasing concentration due to the swelling is simultaneously overcome by the concentration of hydrolysis products. "Rounding off" of the still-living protoplasts of the abscission cells follows and this leads to separation of cells.