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ULTRASTRUCTURE OF MERISTEM AND ROOT CAP OF PEA SEEDLINGS UNDER SPACEFLIGHT CONDITIONS

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16. Abstract
The paper presents data of electron microscopic analysis of meristem and root cap of pea seedlings grown aboard the Salyut-6 orbital research station in the Oazis apparatus and in the laboratory. The main morphological and anatomical characteristics of the test and control plants are shown to be similar. At the same time, some differences are found in the structural and functional organization of the experimental cells as compared to the controls. They concern first of all the plastid apparatus, mitochondria and Golgi apparatus. It is assumed that cell function for certain periods of weightlessness on the whole ensures execution of the cytodifferentiation programs genetically determined on the earth. Biochemical and physiological processes vary rather markedly due to lack of initially rigorous determination.

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For the solution of fundamental and applied problems of space /75*
biology, studies of the growth, reproduction and differentiation of cells, as well as the processes on which growth and development of organisms including plants are based are of real importance [1, 2]. Plants, as regenerators of oxygen and the source of various nutrient substances required by the human body, are a compulsory component of
biological life support systems aboard space flight vehicles, as well /76
as expert model objects.

Aboard the Salyut-6 orbital research station in the Oazis apparatus, experiments were conducted on the cultivation of pea plants (Pioneer variety) for periods of 7 and 18 days. After completion of the experiments, 3 mm long tips of the main roots of the pea plants were prefixed in the laboratory with 2.5% glutaraldehyde solution in phosphate buffer, pH 7.2, for a period of 12 hours, and they were postfixed with 1% OsO_4 solution in the same buffer for 2 hours at room temperature. The material was dehydrated by the generally accepted method in siccative concentration alcohols and propylene oxide, and it was embedded in a mixture of epon and araldite. Sections were prepared in a LKB system ultramicrotome, contrasted with uranyl acetate and lead citrate, and they were then studied in JEM-100B electron microscope.

As the studies showed, the main morphological and anatomical characteristics of the control and test pea plants did not differ. The ultrastructure of the meristem cells of the primary root cortex at the levels of three and two layer caps, the meristem cells of the cap and

*Numbers in the margin indicate pagination in the foreign text.

the central statenchyme were most similar to those of the controls. Some change in ultrastructure of the cells of the test and control versions was established, particularly in the plastid apparatus, mitochondria and Golgi apparatus.

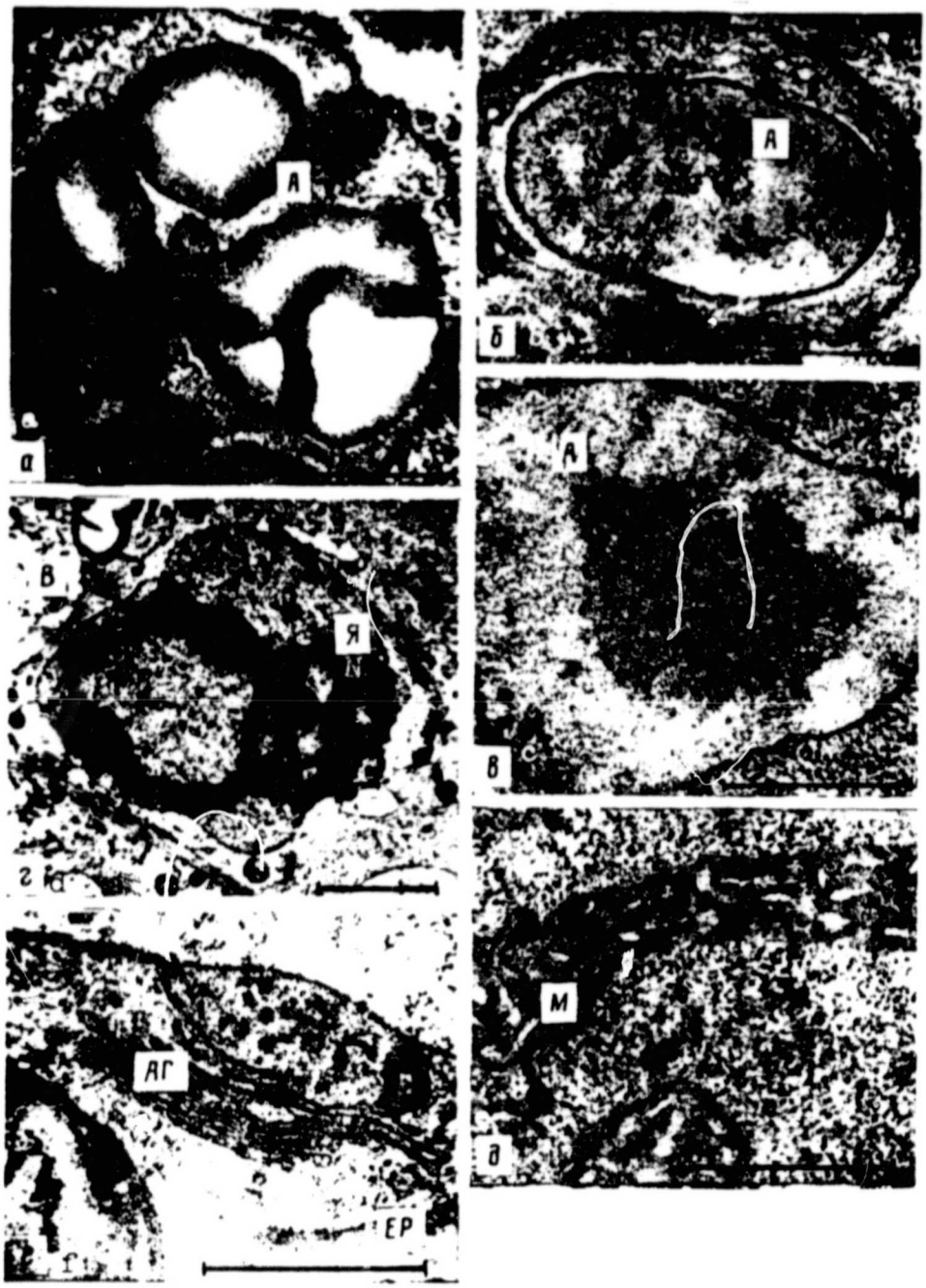
A real singularity in the structure of the plastid apparatus was found in the cells of the central statenchyme of the test plants compared with the controls, in which large size amyloplasts have many starch grains (up to 10-12) and osmiophilic globules. Close stroma, well developed peripheral plastid reticulum which is made up of a system of vesicles and short tubules, as well as inclusions of phytoferritin, an iron containing protein, are characteristic of the amyloplasts. The amyloplasts are located in the distal ends of the cells immediately next to the plasmalemma. There is no clear localization of amyloplasts in the plants grown in weightlessness. They are scattered in different parts of the cells of the central statenchyme above and below the nucleus. Isolated amyloplasts are in the proximal portion of the cell close to the plasmalemma. The stroma of the amyloplast become light and acquire low electron density, the peripheral plastid reticulum is reduced to various degrees, and the size and number of starch grains decreases (in half day pea sprouts, see Figure, a). In the plastids of the 18 day pea plants, the starch is in single large round or oval grains located in the central portions of the organelles in the sections or is completely absent (see Figure, b, c).

In the nuclei of the central statenchyme cells of the test plant roots, disruption of the normal topographic area of diffuse and condensed chromatin of the nucleus was found. The chromatin is in the unusual form of dense conglomerates which occupy a considerable volume of the nucleus (see Figure, d). The increased volume of condensed chromatin evidently indicates a reduction in functional activity of the nuclei, which results in a reduction of different synthesis processes, that of proteins in particular, in the cytoplasmic organelles and hyalopalsm. At the structural level, this is manifested by brightening of the amyloplast stroma and a reduction in their membrane systems. A mutually conditioned change in functional activity of the nucleus and cytoplasmic organelles as a result of weightlessness is

most likely.

Under normal growing conditions, mitochondria with a matrix of medium electron density and empty crists, the topography, size and number of which varies considerably, is characteristic of the meristem cells of the primary root cortex at the three layer cap level. Isolated zones of the matrix may be more electron transparent. DNA fibrils and intramitochondrial granules can be observed in them. In studies of half day pea plants, the density of the mitochondrion matrix is increased and the number of crists increases (see Figure, e). With increase in space flight duration (18 day plants) the heterogeneity of the mitochondrion population in the root meristem cells increases. The correlation between the ultrastructural and functional characteristics of the mitochondria make it possible to suppose that, in weightlessness, the functional activity of the meristem cell mitochondria is substantially weakened, which evidently indicates a reduction in energy exchange in the cells and the respiration rate. /77

The dictyosomes in the meristem cell primary root cortex are made up of an average of 5-6 cisternae, which narrow at the secretory distal ends of the mass and are somewhat widened in the proximal regenerative end. The outline of the cisterna membrane is thin. In the cells studied, a specific change of the peripheral cisternae of the distal secretory pole of the dictyosomes is distinguished (see Figure, f). The variety in synthesis and accumulation of secretion products, which is associated with the different types of activity of the dictyosomes, makes difficult the identification of the functional importance of the rearrangements described at the structural level. However, with the role of the Golgi apparatus in the synthesis and transport of most polysacchrides which are included in the cell membrane taken into account, it can be assumed that the change of the cisternae of the secretory pole of the dictyosome is a measure of damage to these processes, which may be connected with thinning of the membranes of the test cells compared with the controls. It is not excluded that the structural rearrangements of the dictyosomes indicate a change in other functions of the Golgi apparatus besides



Fragments of central statenchyme cells (a-d) and meristem cells (e, f) of roots of 7-day (a,d-f) and 18-day (b,c) pea plants: a. x30,000; b,c. x24,000; d. x15,000; e. x32,000; f.x30,000; A. amyloplast; N. nucleus; B. vacuole.

Key: АГ. Golgi apparatus
M. Mitochondrion

the processes of accumulation, growth and specialization of the membranes, which undoubtedly damages the dynamic equilibrium between the phases of metabolism in the meristem cells.

The endoplasmic reticulum is short, and the longitudinal profiles of the granular type cisternae are oriented in different directions in relation to the cell membrane. The position of the membranes of the endoplasmic reticulum parallel to each other and to the cell membrane was distinguished. Broadening of the cisternae which do not have ribosomes of round or oval shape in the sections frequently is found. The location of the cisternae of the endoplasmic reticulum can be more electron transparent than that of the control cells of the central statenchyme.

Vacuolization of the root meristem cells of half day pea plants is similar to that in the controls, but it is intensified in the 18 day plants. Progressive vacuolization is characteristic of the central statenchyme cells of the test plants.

The rearrangements described of the ultrastructural organization of the cell organelles indicate a change in cell metabolism, and they confirm the data of [3-6], which were obtained by the use of biochemical and other methods of study of grass and plant organisms with change of carbohydrate and lipid metabolism in space flight conditions, and an increase or decrease in activity of a number of enzymes.

Thus, during the entire time of exposure to weightlessness, the program of cytodifferentiation genetically determined on the earth is ensured in the functioning of the cells as a whole. The biochemical and physiological processes change rather markedly due to the lack of initially rigorous determination.

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