DIVISION MECHANISM ESTABLISHMENT BY SINGLE ASTERS IN SAND DOLLAR (ECHINARACHNIUS PARMA) EGGS

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The division mechanism of animal cells is established in the cortex between the asters of the mitotic apparatus (MA), and that geometrical relation has been incorporated as an essential element in conjectures about the establishment of the mechanism and its function. Although a single aster fails to establish a furrow in a spherical cell, it can do so in a cylindrical cell, and the reason for its efficacy in the latter case has been attributed to altered geometrical circumstances (Rappaport & Rappaport, J. Exp. Zool. 235: 217-226, 1985). In cylindrical cells with a broken MA, well-developed furrowing is associated with only one of the two asters present. The purpose of this investigation was to extend the study of division mechanism formation in this circumstance using improved methods of observation and experimentation.

Mechanically denuded sand dollar eggs were kneaded about 45 min after fertilization by pipeting to break the MA. Eggs were then confined in a thin-roofed silicone rubber capillary about 85 μm in diameter. Reshaping the egg into a cylinder provided better observation and control of the relation between the MA or its parts and the surface. Asters were moved by local compression of the capillary wall with a glass ball. Observation with Hoffman modulation contrast optics revealed that the MA was by chance broken into 2 or 3 parts. When broken into 3 parts, the nucleus and the 2 asters were completely separated, and when broken into 2 parts (which was most frequent) the nucleus was attached to one of the asters. Subsequent development of the asters depended upon their association with the nucleus. Those that formed in association with the nucleus contained a larger clear central area and stouter straight rays. Their development lagged behind that of enucleate asters. General shrinkage of the cell margin but no distinct furrows developed near enucleate asters. Furrows capable of completion developed in association with nucleated asters. About half the furrows began in the plane of the aster center and then slid to one side of it where they completely divided the cells. When the aster was held in the cleavage plane the furrow regressed. Nuclei that were completely separated from the mitotic asters elicited furrows provided astral rays developed around them. Cortical contractile activity in operated cylindrical cells began later than furrowing in spherical control cells. Nucleated asters established functional division mechanisms when they were kept in reciprocating motion beginning before the time of furrow establishment in the cortex. When the nucleated aster was moved shortly after the furrow appeared, the furrow shifted or formed de novo in the same relation to the aster in its new position and the constriction in the original plane regressed.

These results indicate that in cylindrical sand dollar eggs a single nucleated aster can function in cytokinesis in the same way as the intact MA. They also offer the strongest support now available for the idea that the MA elicits the division mechanism by microtubule-dependent transport of contraction promoter from the region of the mitotic axis to the cortex.

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