A NEW WORKING HYPOTHESIS FOR THE STRUCTURE AND FUNCTION OF THE GOLGI APPARATUS IN PLANT CELL WALL BIOGENESIS

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It is the general belief of many investigators that the pathway of cellulose biogenesis occurs via soluble pools of hexose phosphate monomers and the plasma membrane which is thought to be the site of polymerization and/or crystallization (2). Brown and coworkers (1) and Ray (see 1) have proposed to the contrary that the Golgi apparatus is the site of cellulose biogenesis in certain scale-producing algae and higher plants respectively. While it has been fairly well established that cellulose can be biosynthesized by the Golgi apparatus (1), considerable doubt has been expressed that this type of system could be applicable to cellulose biogenesis in higher plant systems (2). Conversely, the problems associated with in vitro cellulose biosynthesis in Golgi-enriched homogenates raises questions about the in vivo localization of B-(1,4)-glucan synthetase activity.

Two model systems of cellulose biogenesis have been selected for investigation. These include the haptophycean scale producer, Pleurochrysis and another alga Glaucocystis which produces a cell wall of organized cellulose microfibrils (2), similar to the secondary wall of xylem. In Pleurochrysis, the scale is composed of radial, non-cellulosic microfibrils, upon which is deposited a spiral band of 8 to 10 parallel cellulose microfibrils (Fig.1). The microfibrillar skeleton can be coated with amorphous polysaccharide. Only the amorphous and radial microfibrillar components react with silver methenamine. This differential staining (Fig.2) has permitted a more accurate assessment of the biogenetic pathway which is outlined as follows: (1) Golgi cisternal membranes are pre-assembled within specific regions of the rough ER; (2) precursor pools for radial and cellulosic microfibrils can be recognized while still attached to the ER; (3) these pools become integrated as dilations in the first-formed Golgi cisternae; (4) from the radial precursor pool, radial microfibrils are synthesized in a folded configuration; (5) after unfolding, the cellulosic precursor pool synthesizes cellulose microfibrils which are fed through a central feeding tubule on the distal side of the cisterna; and (6) amorphous polysaccharide material originates only in vegetative cells from budding vesicles of the rough ER which migrate and fuse with the periphery of distal cisternae, causing scale adhesion to form the wall. Glaucocystis, on the other hand, produces a cell wall of continuous cellulose microfibrils which lie in multiple layers approximately 90° to one another (Fig.3). These microfibrils originate from a modified Golgi apparatus composed of subsurface cisternae which underlie the plasma membrane (Fig.4). Rows of cellulosic microfibrillar feeding tubules connect the subsurface cisternal membrane to the plasma membrane in the furrow region. The cell surface must rotate on two axes to explain the organized deposition of cellulose microfibrils. Several motile mechanisms will be discussed. Non-cellulosic material coating the surface of the cellulosic microfibrils is produced by a "classical" Golgi apparatus in Glaucocystis. Glaucocystis and Pleurochrysis will be compared with other polysaccharide synthesizing systems, and a generalized pathway for the ER and the Golgi apparatus in polysaccharide biosynthesis will be outlined (Fig.5).

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Fig. 1: Cellulosic scale of Pleurochrysis showing radial and spiral microfibrils.

Fig. 2: Scale biogenesis in the Golgi apparatus of Pleurochrysis.

Fig. 3: Expanded cellulosic microfibrillar wall of Glaucocystis

Fig. 4: Modified Golgi apparatus of Glaucocystis.

Fig. 5: Schematic diagram of a generalized pathway for the endoplasmic reticulum and Golgi apparatus in polysaccharide biogenesis.