The Golgi Apparatus

(how to become fascinator starting by being suspect)

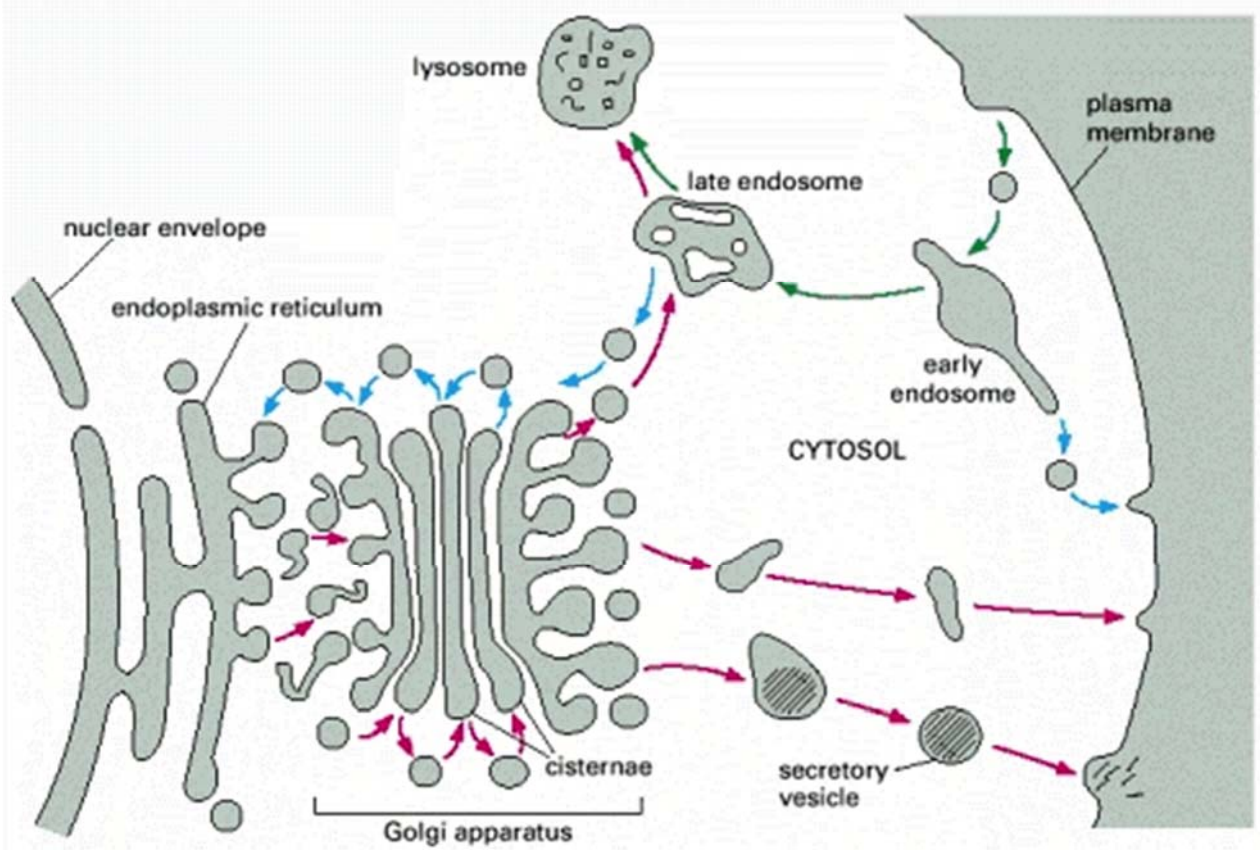
Definition

Structure, ultrastructure

Functions

Golgi-RE cross-talk in membrane biogenesis and intracellular traffic

Cellular structures acting in membrane biogenesis and traffic



Golgi Complex under light microscopy

1898
Nobel Prize winner,
1906

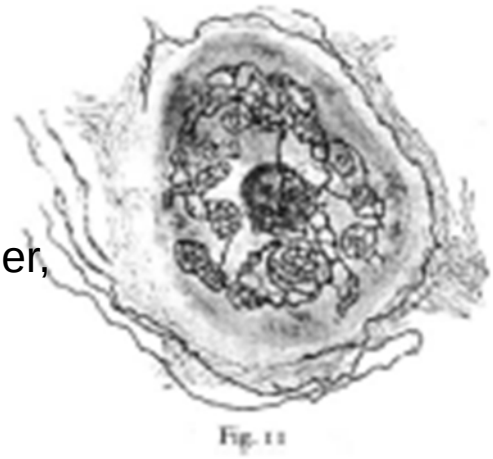
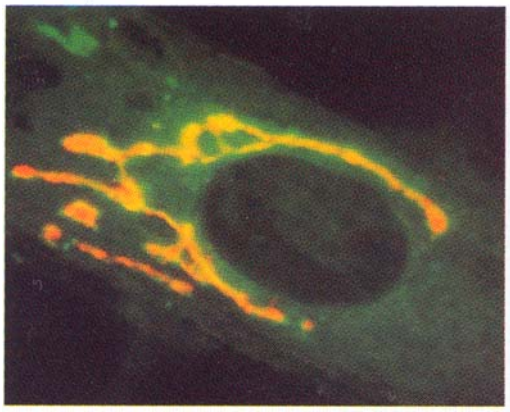


Fig. 11

Camillo Golgi (1843-1926)



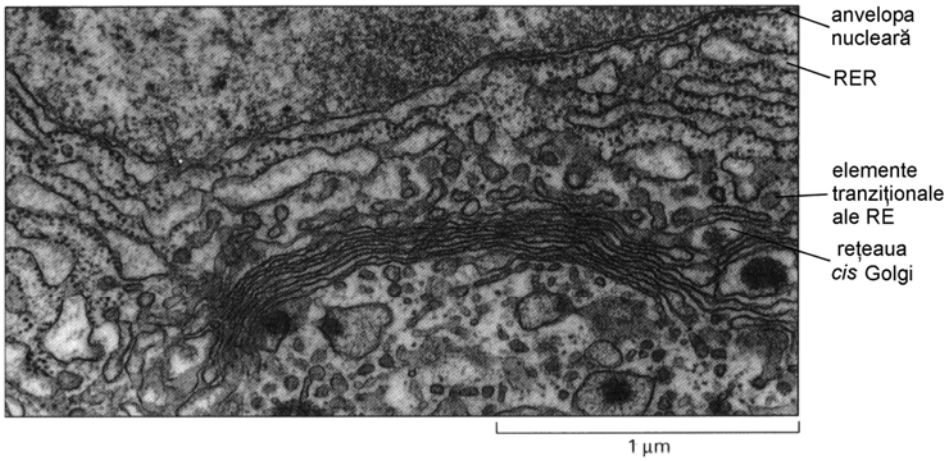
History

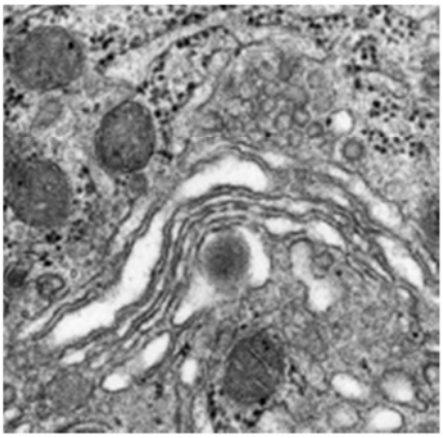
TABLE 1 – SOME IMPORTANT MILESTONES IN GOLGI RESEARCH

Year	Event	Discoverer(s)
1898	Discovery of the Golgi apparatus	Golgi
1954	First electron microscopy (EM) description of the Golgi apparatus	Dalton and Felix
1957	Cisternal maturation model of Golgi transport	Grassé
1961	Compartmentalization: regional distribution of enzymes	Novikoff and Goldfischer
1964	Involvement in sulfation	Godman and Lane
1966	Involvement in glycosylation: glucose incorporation	Neutra and Leblond
1967–1975	Role in secretory pathway defined and vesicular transport documented	Palade, Jamieson and coworkers
1969	Incorporation of mannose in endoplasmic reticulum (ER), galactose in Golgi	Whur, Herscovics and Leblond
	Galactosyltransferase as a biochemical marker for the Golgi apparatus	B. Fleischer *et al.*; Morré *et al.*
1971	GERL concept	Novikoff and Novikoff
1973–1981	Role of mannose 6-phosphate in lysosomal enzyme sorting by Golgi	Sly, Neufeld, Kornfeld, Jourdian
1977	Demonstration of recycling plasma membrane to Golgi	Herzog and Farquhar
1980	Introduction of glycosidase (endo H) treatment to assess transport	Strous and Lodish
1981–1983	Topology of N-glycosylation	Dunphy and Rothman
	Immunocytochemical localization of galactosyltransferase to *trans* Golgi	Roth and Berger
	Reconstitution *in vitro* of transport within Golgi stack	Rothman *et al.*
1984	Description of 15° block and cargo accumulation in pre-Golgi intermediate compartment	Saraste and Kuismanen
1985	Regulated vs. constitutive secretory pathways	Moore and Kelly
1986	Description of 20° block and cargo accumulation in *trans*-Golgi network (TGN)	Griffiths and Simons
1987	Transmembrane domain required for retention of resident Golgi proteins	Machamer and Rose
	KDEL retrieval signal for resident ER proteins	Munro and Pelham
	Involvement of small GTP-binding proteins in vesicular transport	Salminen and Novick
	Heterotrimeric G-proteins implicated in traffic control	Melançon *et al.*
	Reconstitution *in vitro* of ER-to-Golgi transport	Becker and Balch
1988	Isolation of ER–Golgi intermediate compartment (ERGIC)	Schweizer *et al.*
1990	Application of brefeldin A to study Golgi–ER transport	Lippincott-Schwartz *et al.*
	Phosphoinositide 3-kinase implicated in control of Golgi traffic	Herman and Emr; Schu *et al.*
1991	Discovery of COPI coat	Duden *et al.*; Serafini *et al.*; Waters *et al.*
	Demonstration of role of Goi3 in traffic control	Stow *et al.*
1993–1994	Demonstration that ER-to-Golgi transport is selective	Balch *et al.*; Mizuno and Singer; Rexach *et al.*
1994	Discovery of COPII coated vesicles	Barlow *et al.*
	COPI functions in Golgi-to-ER retrograde transport	Letourneur *et al.*

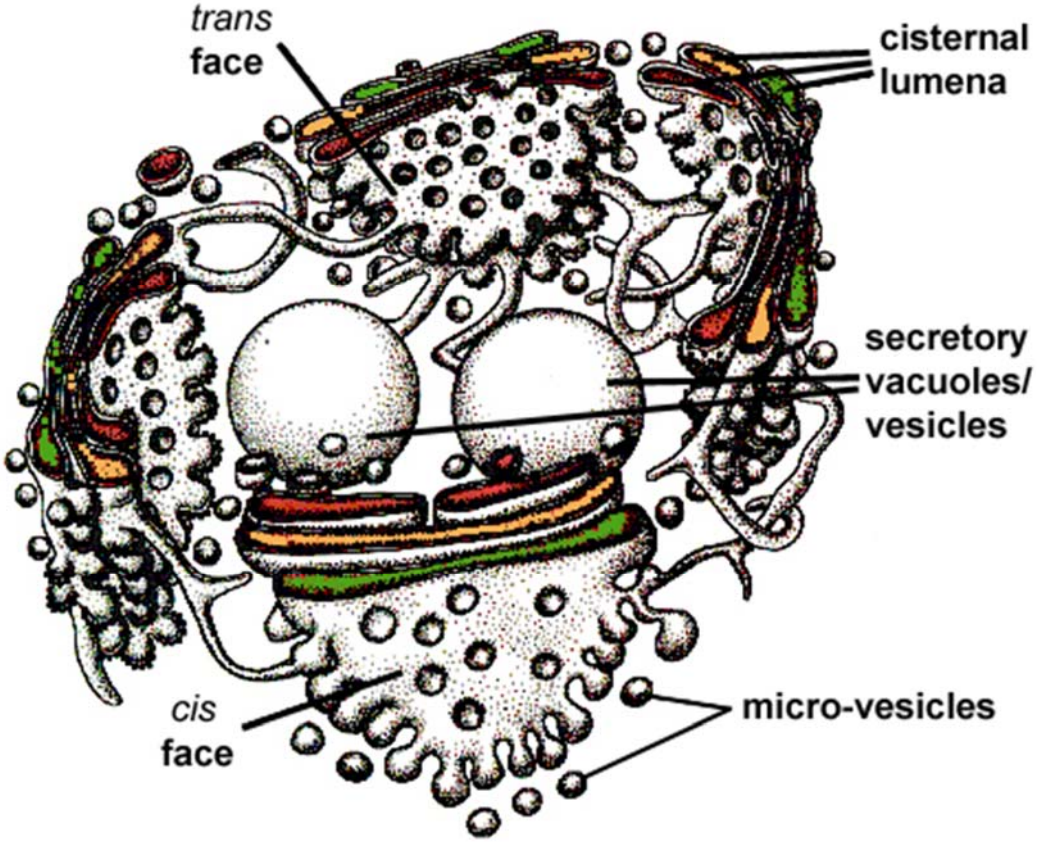
From:
Fraquhar MG, Palade GE. (1998) ***The Golgi apparatus: 100 years of progress and controversy***. *Trends in Cell Biology*, 8, 2-10

Golgi Complex Ultrastructure





3D Organization of Golgi Complex

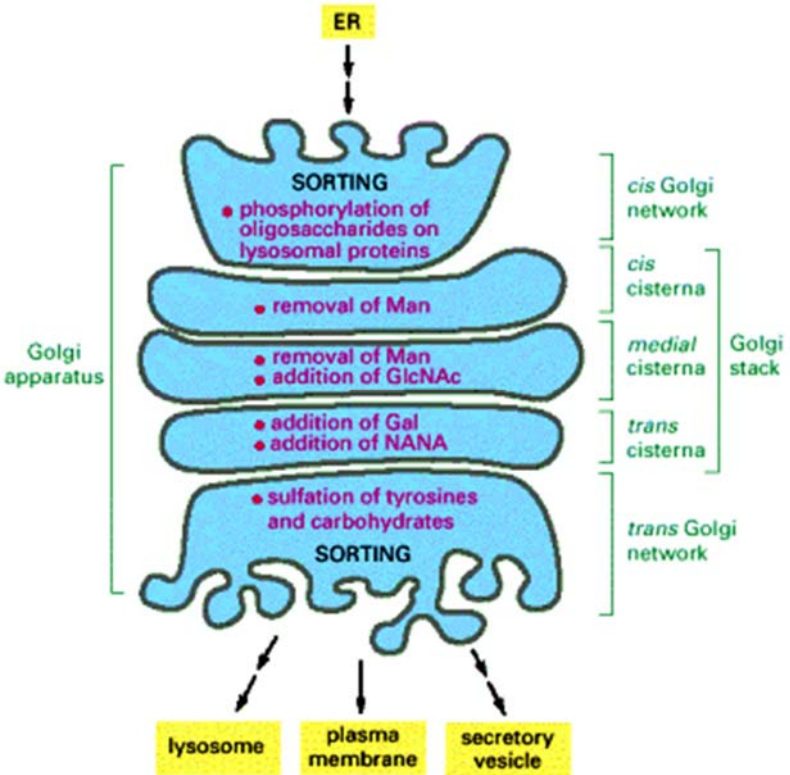


Functions of Golgi Apparatus

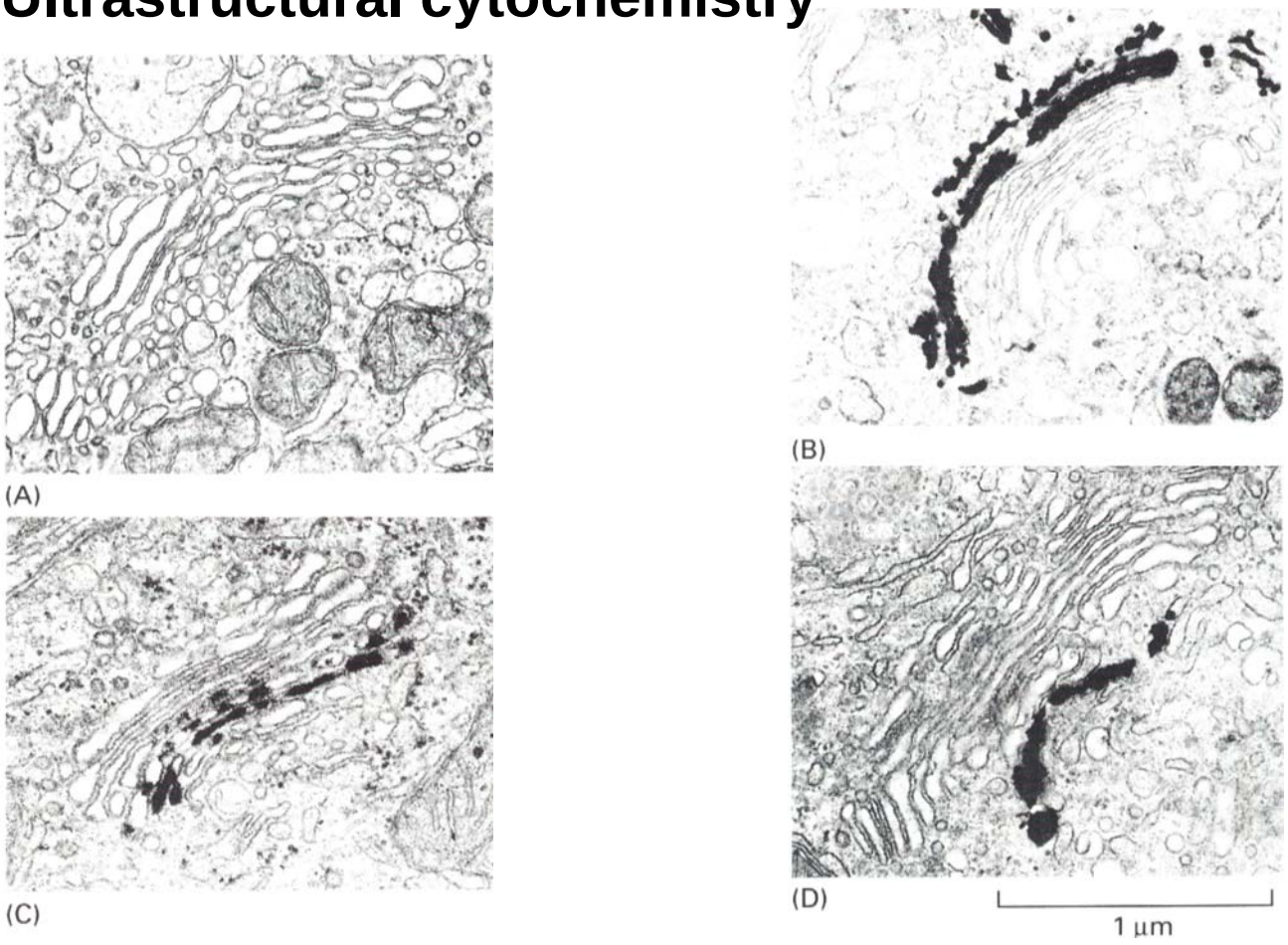
1. Sphingolipid processing (sphingomyelin, glycolipids);
2. Protein glycosylation (terminal glycosylation of ***N***-linked glycans, ***O***-linked glycans producing);
3. Glycosaminoglycans (GAG) biosynthesis;
4. Sulfation of some sugars (glycoproteins, GAGs);
5. Synthesis of the mannose-6-phosphate marker on lysosomal hydrolases, and lysosome biogenesis;
6. Protein maturation;
7. Sorting and transport of biomolecules to final cellular location.

N.B. Step by step ordered biochemical events in Golgi apparatus

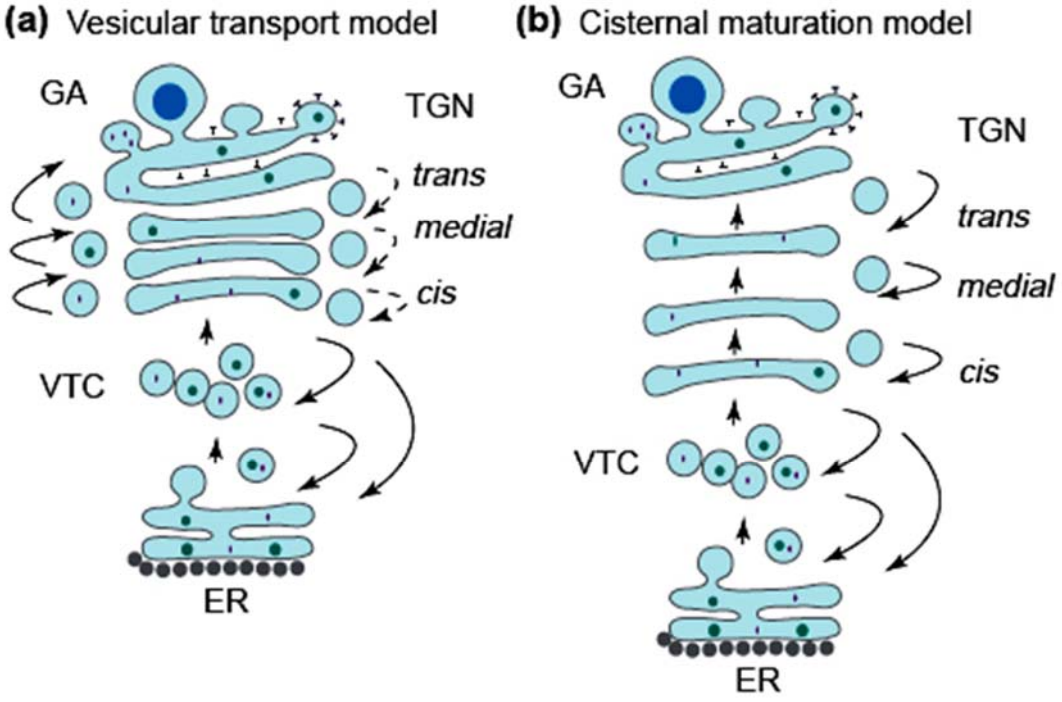
Biochemical polarization of the Golgi Complex



Ultrastructural cytochemistry



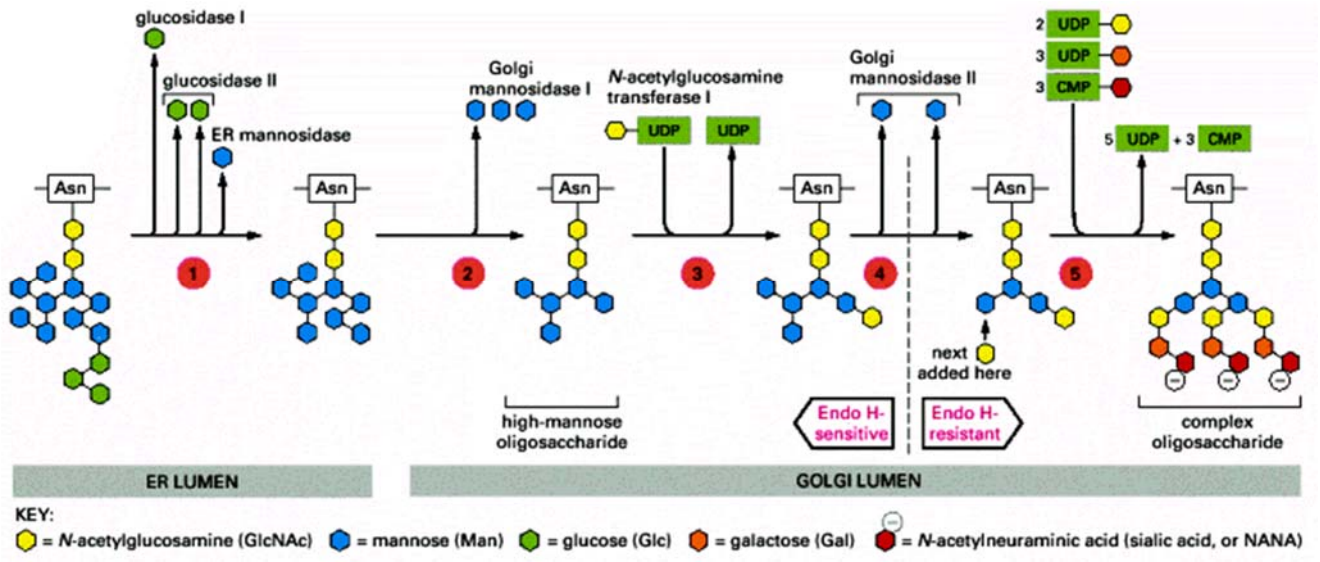
Models Concerning Golgi Apparatus Dynamics



From: Storrie B, Pepperkok R, Nilsson T – ***Trends in Cell Biology***, **10**, 385-391 (2000)

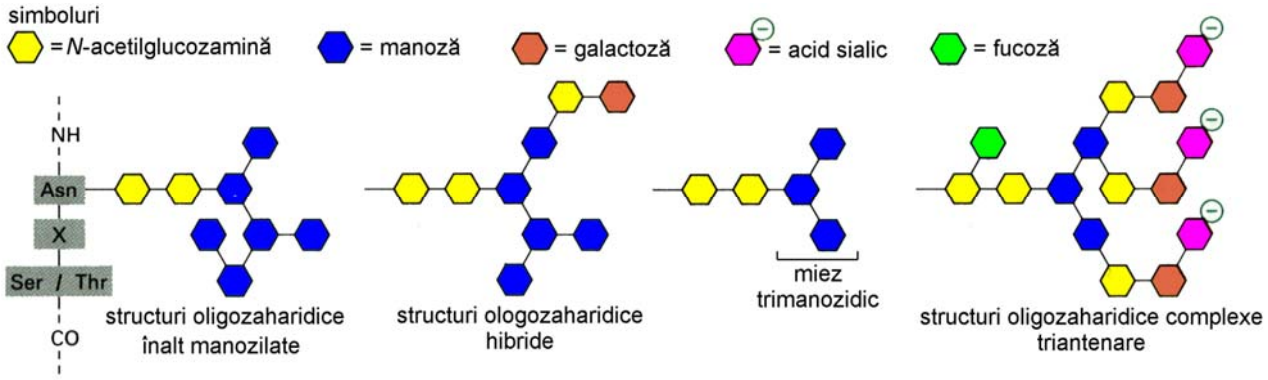
Processing of *N*-linked glycans

Mannose trimming and terminal processing of N-linked glycans



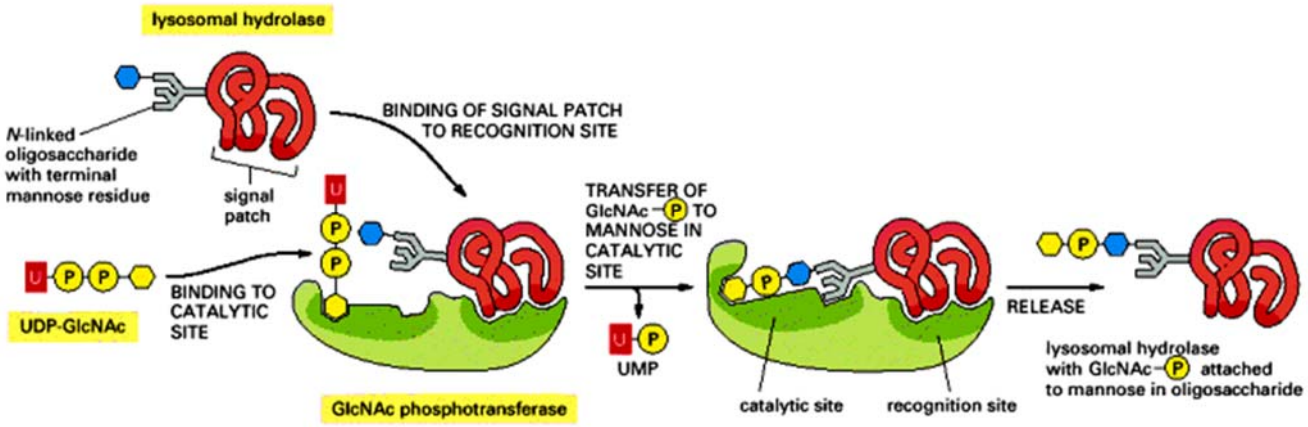
Oligosaccharide Structures Produced in Golgi Complex

1. *N*-linked oligosaccharides



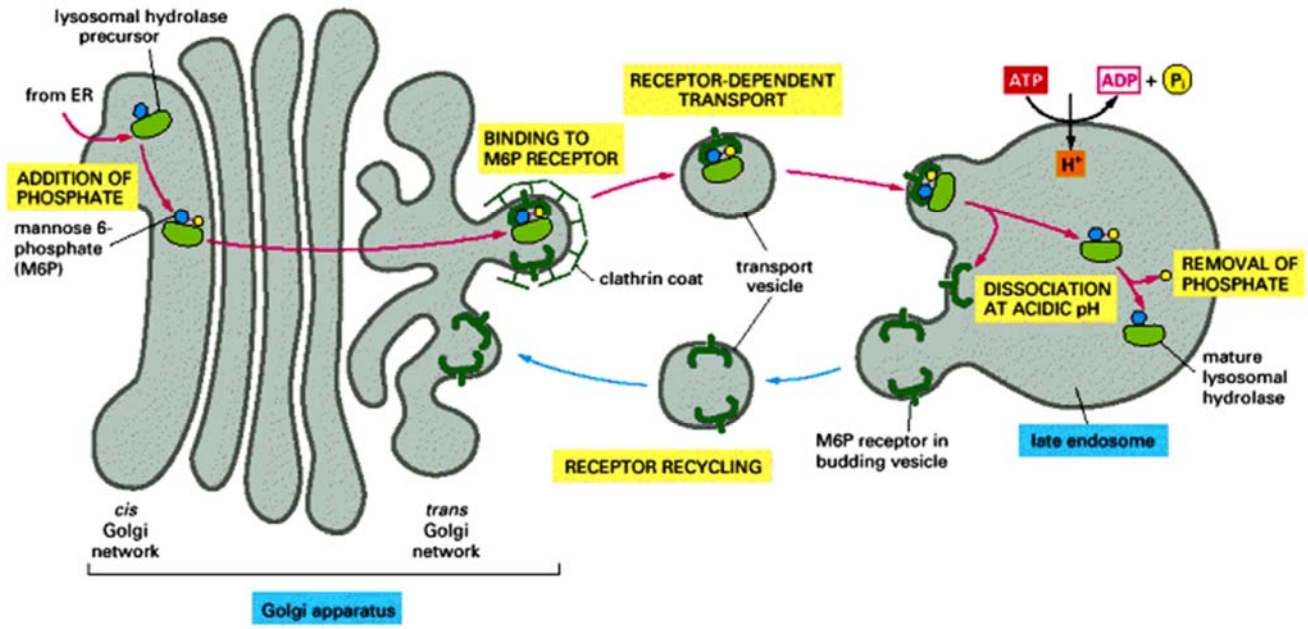
2. *O*-linked oligosaccharides

Synthesis of the Mannose-6-phosphate Marker on Lysosomal Hydrolases



These events belong to the lysosome biogenesis

Lysosome Biogenesis



1. Labeling of lysosomal enzymes, in *cis* area
2. Transport from *cis*-face toward *trans*-face, and maturation
3. Sorting and budding, in *trans* area, as primary lysosomes
4. Fusion with late endosomes or already existing secondary lysosome

Golgi – ER Cross-talk in Membrane Biogenesis and Intracellular Traffic

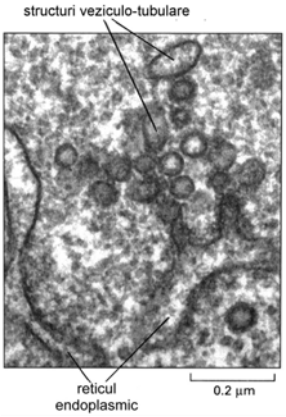
- Membrane biogenesis
- ER to Golgi traffic;
- Golgi to cell membrane / endosomal system traffic;
- Cell secretion

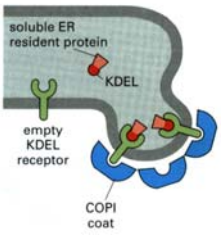
Membrane Biogenesis

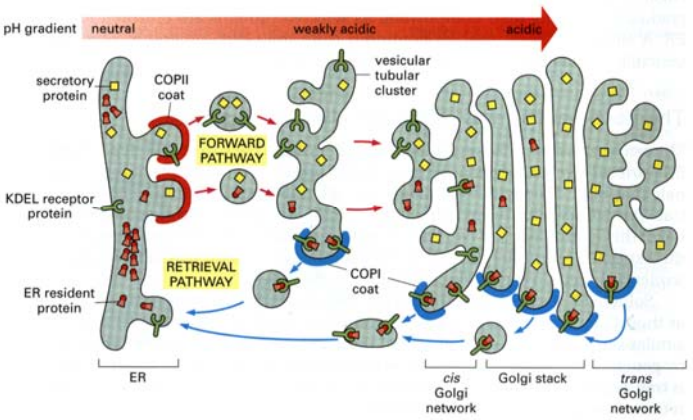
- A complex process involving several organelles:
  - Ribosome;
  - Endoplasmic reticulum;
  - Golgi apparatus.
- Consists in:
  - Biosynthesis of molecules/macromolecules organizing membranes;
  - Correct assembly of molecular components in the structure;
  - Structure maturation to become functional;
  - Directional transport of the new membranes to final location.
- Claims a well elaborated and controlled membrane traffic

ER to Golgi Traffic

- Sorting at the tranzitional ER level (COP II, Sar1);
- Traffic to Golgi apparatus;
- Sorting at the Golgi complex (COP I, Arf1);
- Returning to ER (recycling of some components).





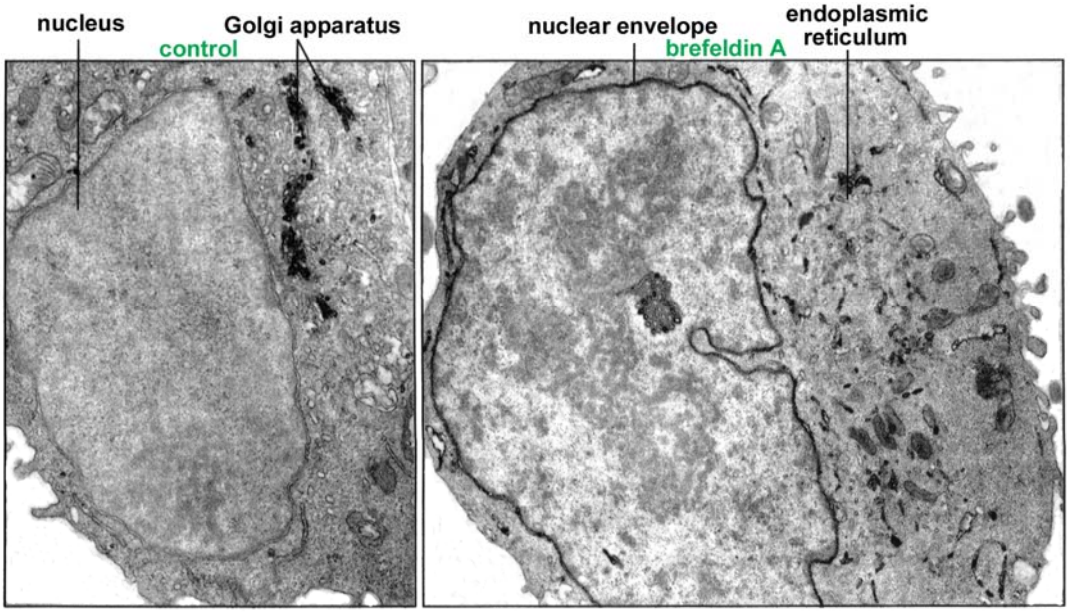


Conclusion: ER to Golgi transport fits to a vesicular transport (a shuttle mechanism)

Jennifer Lippincott-Schwartz (NIH)

Experimental proves for the shuttle mechanism

1989: Brefeldin A inhibits forward transport from ER to Golgi, COP II dependent

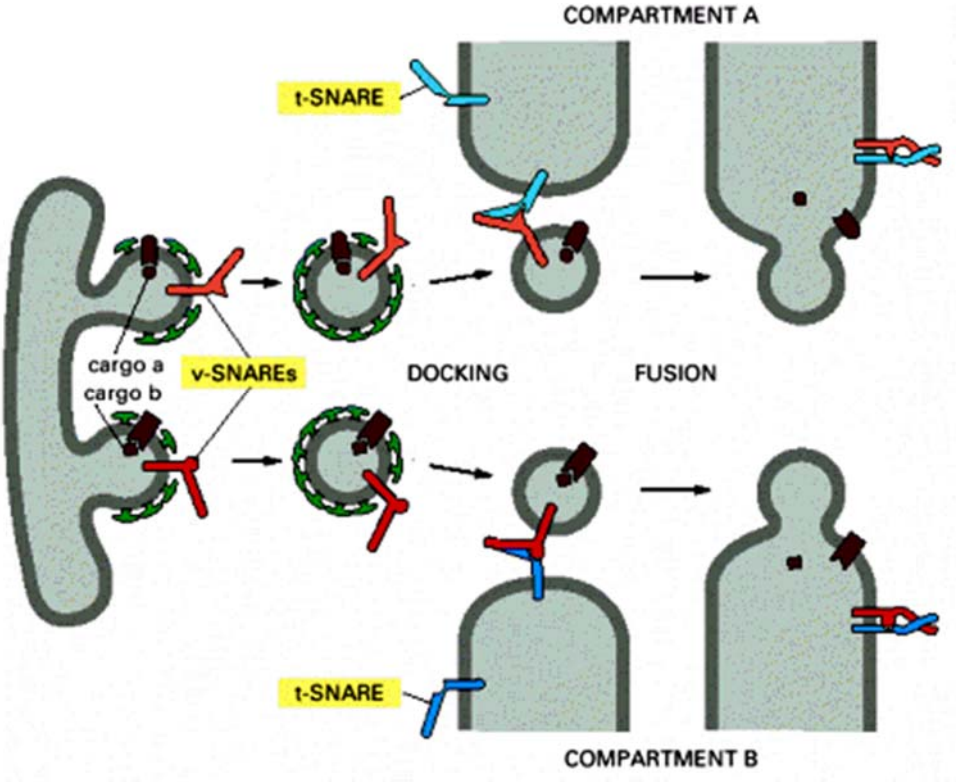


Golgi to Final Location Traffic

= *trans*-Golgi network (TGN) role =

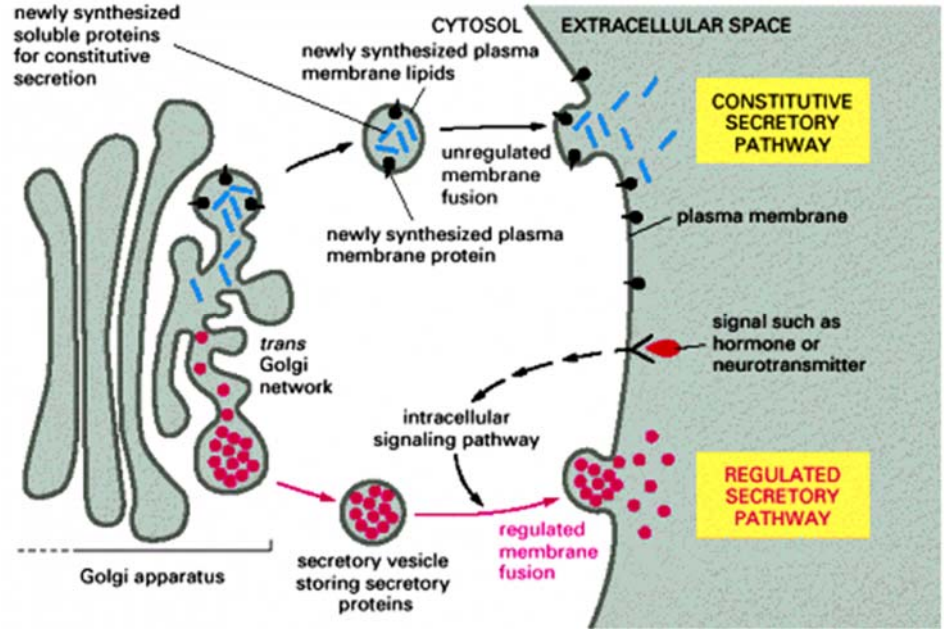
- **Golgi to lysosome:** sorting by M6P, segregation and vesiculation by adaptor proteins (AP3) and clathrin coat;
- **Golgi to apical membrane:** sorting by luminal mechanisms and lipid rafts, cooperative transport by dynein (microtubule route, – end), and myosin (F actin route);
- **Golgi to lateral-basal membrane:** sorting by amino acid motifs, transport by kinesin (microtubule route, + end);
- **Control and Regulation:** by small GTP-ases (monomeric G proteins);
- **Direction Control:** by SNARE (v-SNARE, and t-SNARE)

Directed vesicular transport by specific SNAREs



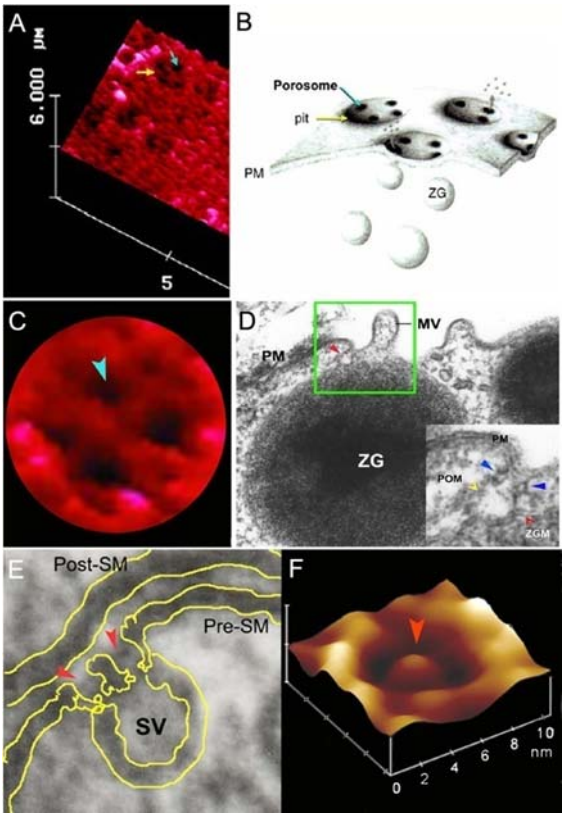
Cell Secretion

- Biosynthesis of secretory proteins;
- Processing (maturation), sorting and condensation in secretory vesicles/vacuoles;
- Scretion (constitutive, or signal regulated).



Porosome

- Membrane microdomain
- Universal portal of cell secretion
- Nanostructure to be deciphered in terms of molecular organization



Courtesy of Dr. Bahnu Jena,
George E. Palade University Professor,
Department of Physiology,
Wayne State University
School of Medicine
Director,
NanoBioScience Institute,
Detroit, Michigan, USA

Summary

- Golgi apparatus – the only organelle which captivated scientist initially by suspicion, later by structural and functional complexity;
- Shows ultrastructural polarity, but also a biochemical one between cisterns;
- Acts in a step by step well ordered manner;
- Functions as a turntable maturing, sorting and directing lysosome, membrane, and secreted components.