

Reading resources for 7.61 Graduate Cell Biology, Fall 2006

7.61 Membrane Trafficking Lecture 12

Textbooks

Lodish 5th ed:

Chapter 16: Moving proteins into membranes and organelles

Chapter 17: Vesicular Traffic, secretion, and endocytosis

Alternative: Lodish 4th ed: see chapter 17

Alberts 4th ed:

Chapter 12 Intracellular Compartments and Protein Sorting

Chapter 13 Intracellular Vesicular Traffic

Additional reading resources (not required)

Reviews

See Current Opinion in Cell Biol. (August issue every year has sorting and membrane transport reviews)

Helenius A, Aebi M. Roles of N-linked glycans in the endoplasmic reticulum. *Annu Rev Biochem.* 2004;73:1019-49.

Fullekrug J, Simons K. Lipid rafts and apical membrane traffic. *Ann N Y Acad Sci.* 2004 Apr;1014:164-9

Mostov K, Su T, ter Beest M. Polarized epithelial membrane traffic: conservation and plasticity. *Nat Cell Biol.* 2003

Apr;5(4):287-93.

van Vliet C, Thomas EC, Merino-Trigo A, Teasdale RD, Gleeson PA. Intracellular sorting and transport of proteins. *Prog Biophys Mol Biol.* 2003 Sep;83(1):1-45.

Loh YP, Maldonado A, Zhang C, Tam WH, Cawley N. Mechanism of sorting proopiomelanocortin and proenkephalin to the regulated secretory pathway of neuroendocrine cells. *Ann N Y Acad Sci.* 2002 Oct;971:416-25.

Ait Slimane T, Hoekstra D. Sphingolipid trafficking and protein sorting in epithelial cells. *FEBS Lett.* 2002 Oct 2;529(1):54-9.

TAEYOON KIM, JUNG-HWA TAO-CHENG, LEE E. EIDEN, and Y. PENG LOH Large Dense-Core Secretory Granule Biogenesis Is under the Control of Chromogranin A in Neuroendocrine Cells *Ann NY Acad Sci* 2002 971: 323-331.

Cohen JC, Kimmel M, Polanski A, Hobbs HH. Molecular mechanisms of autosomal recessive hypercholesterolemia. *Curr Opin Lipidol.* 2003 Apr;14(2):121-7.

Marsh BJ, Howell KE. Timeline: The mammalian Golgi - complex debates. *Nat Rev Mol Cell Biol.* 2002 Oct;3(10):789-95.

Pelkmans L, Helenius A. Endocytosis via caveolae. *Traffic.* 2002 May;3(5):311-20.

Rothman JE. The machinery and principles of vesicle transport in the cell. *Nat Med.* 2002 Oct;8(10):1059-62.

Wickner W. Yeast vacuoles and membrane fusion pathways. *EMBO J.* 2002 Mar 15;21(6):1241-7.

Shimoni Y, Schekman R. Vesicle budding from endoplasmic reticulum. *Methods Enzymol.* 2002;351:258-78.

Razani B, Woodman SE, Lisanti MP. Caveolae: from cell biology to animal physiology. *Pharmacol Rev.* 2002 Sep;54(3):431-67.

SIGNAL TRANSDUCTION: A New Thread in an Intricate Web Mark von Zastrow and Keith Mostov *Science* Nov 30 2001: 1845-1847.Lee AS. The glucose-regulated proteins: stress induction and clinical applications. *Trends Biochem Sci.* 2001 Aug;26(8):504-10.

Gu F, Crump CM, Thomas G. Trans-Golgi network sorting. *Cell Mol Life Sci.* 2001 Jul;58(8):1067-84.

Antony B, Schekman R. ER export: public transportation by the COPII coach. *Curr Opin Cell Biol.* 2001 Aug;13(4):438-43

Ellgaard L, Helenius A. ER quality control: towards an understanding at the molecular level. *Curr Opin Cell Biol.* 2001 Aug;13(4):431-7.

Helenius A, Aebi M. Intracellular functions of N-linked glycans. *Science.* 2001 Mar 23;291(5512):2364-9.

<http://bio3d.colorado.edu/pubs/Golgi/GolgiAnalysis.html>

Hugh R. B. Pelham and James E. Rothman The Debate about Transport in the Golgi—Two Sides of the Same Coin? *Cell*, Vol. 102, 713–719, September, 2000,

Keith E Mostov, Marcel Verges, Yoram Altschuler Membrane traffic in polarized epithelial cells *Current Opinion in Cell Biology* 2000, 12:483-490.

Benjamin S Glick Organization of the Golgi apparatus *Current Opinion in Cell Biology* 2000, 12:450-456.

- Judith Klumperman Transport between ER and Golgi Current Opinion in Cell Biology 2000, 12:445-449.
- Alain Prochiantz Messenger proteins: homeoproteins, TAT and others Current Opinion in Cell Biology 2000, 12:400-406.
- Sandra K Lemmon, Linton M Traub Sorting in the endosomal system in yeast and animal cells Current Opinion in Cell Biology 2000, 12:457-466.
- Jahn R, Sudhof TC. Membrane fusion and exocytosis Annu Rev Biochem. 1999;68:863-911
- Scott D Emr and Vivek Malhotra: Membranes and sorting [Editorial overview] Current Opinion in Cell Biology 1997 9 :475-476.
- Meta J Kuehn and Randy Schekman: COPII and secretory cargo capture into transport vesicles [Review article] Current Opinion in Cell Biology 1997 9 : 477-483.
- Pierre Cosson and Francois Letourneur: Coatomer (COPI)-coated vesicles: role in intracellular transport and protein sorting [Review article] Current Opinion in Cell Biology 1997 9 : 484-487.
- Tomas Kirchhausen, Juan S Bonifacino and Howard Riezman: Linking cargo to vesicle formation: receptor tail interactions with coat proteins [Review article] Current Opinion in Cell Biology 1997 9 : 488-495.
- Peter Novick and Marino Zerial: The diversity of Rab proteins in vesicle transport [Review article] Current Opinion in Cell Biology 1997 9 : 496-504.
- Jesse C Hay and Richard H Scheller: SNAREs and NSF in targeted membrane fusion [Review article] Current Opinion in Cell Biology 1997 9 : 505-512.
- Yukiko Goda and Thomas C Südhof: Calcium regulation of neurotransmitter release: reliably unreliable? [Review article] Current Opinion in Cell Biology 1997 9 : 513-518.
- Michael G Roth and Paul C Sternweis: The role of lipid signaling in constitutive membrane traffic [Review article] Current Opinion in Cell Biology 1997 9 : 519-526.
- Linton M Traub and Stuart Kornfeld: The trans-Golgi network: a late secretory sorting station [Review article] Current Opinion in Cell Biology 1997 9 : 527-533.
- Thomas Harder and Kai Simons: Caveolae, DIGs, and the dynamics of sphingolipid-cholesterol microdomains [Review article] Current Opinion in Cell Biology 1997 9 : 534-542.
- R. Schekman & L. Orci "Coat Proteins and Vesicle Budding" Science 271: 1526-1533
- P. DeCamilli, S.D. Emr, P. S. McPherson, P. Novick "Phosphoinositides as regulators in membrane traffic" Scinece 271: 1533-1539 (1996)
- M. Aridor & W. E. Balch "Principles of selective transport: coat complexes hold the key" TICB, 6:315-320 (1996)
- Joel Moss and Martha Vaughan. Structure and Function of ARF Proteins: Activators of Cholera Toxin and Critical Components of Intracellular Vesicular Transport Processes. *J. Biol. Chem.* 1995; 270: 12327-12330.
- Nina R Salama and Randy W Schekman: The role of coat proteins in the biosynthesis of secretory proteins [Review article] Current Opinion in Cell Biology 1995 7 : 536-543.
- Mark K Bennett: SNAREs and the specificity of transport vesicle targeting [Review article] Current Opinion in Cell Biology 1995 7 : 581-586.
- Jonathan R Monck and Julio M Fernandez: The fusion pore and mechanisms of biological membrane fusion [Review article] Current Opinion in Cell Biology 1996 8 : 524-533.
- Rothman, J. E. *Nature* 372: 55-63 (1994)
- Balch, W. E. (1989). Biochemistry of interorganelle transport. A new frontier in enzymology emerges from versatile *in vitro* model systems. *J Biol. Chem.* 264, 16965-16968.
- Balch, W. E. (1990). Molecular dissection of early stages of the eukaryotic secretory pathway. *Curr Opin. Cell Biol.* 2, 634-641.
- Nuoffer, C. and Balch, W. E. (1994) *Annu. Rev. Biochem.* 63:949-990.
- Bennett, M. K., and Scheller, R. H. (1993). The molecular machinery for secretion is conserved from yeast to neurons. *Proc. Natl. Acad. Sci. USA* 90, 2559-2563.
- Bennett, M. K., and Scheller, R. H. (1994). A molecular description of synaptic vesicle membrane trafficking *Annu. Rev. Biochem.* 63:63-100.
- Rothman, J. E., and Orci, L. (1992). Molecular dissection of the secretory pathway. *Nature* 355, 409-415.
- Pryer, N. K., Wuestehube, L. J., and Schekman, R. (1992). Vesicle-mediated protein sorting. *Annu. Rev. Biochem.* 61, 471-516.
- Warren, G. (1993). Bridging the gap. *Nature* 362, 297-298.
- "Mitosis and membranes" G. Warren (1989) *Nature* 342: 857-858. membranous organelles disassemble and reassemble after, permits partitioning via vesiculation, cdc2 inhibits invitro assays
- Rothman, J. E., and G. Warren. 1994. Implications of the SNARE hypothesis for intracellular membrane topology and dynamics. *Current Biol.* 4:220-233.
- Ferro-Novick, S. and Jahn, R. (1994) Vesicle fusion from yeast to man *Nature* 370:191-193.
- Palade (*Science* 189 347-358 1975)EM autorad in pancreas

Glycosylation:

- Ghosh P, Dahms NM, Kornfeld S. Mannose 6-phosphate receptors: new twists in the tale. *Nat Rev Mol Cell Biol.* 2003 Mar;4(3):202-12. Related Articles, Links
- Kornfeld, R., and S. Kornfeld. 1985. Assembly of asparagine-linked oligosaccharides. *Ann. Rev. Biochem.* 54:631-634.
- Doms, R. W., R. A. Lamb, J. K. Rose, and A. Helenius. 1993. Folding and assembly of viral membrane proteins. *Virology* 193:545-562.
- Hirschberg, C. B., and M. D. Snider. 1987. Topography of glycosylation in the rough endoplasmic reticulum and golgi apparatus. *Ann. Rev. Biochem.* 56:63-87.
- D. E Goldberg and S. Kornfeld "Evidence for extensive subcellular organization of asparagine-linked oligosaccharide processing and lysosomal enzyme phosphorylation" *J. Biol. Chem.* 258 (1983):3159-3165. One of the early studies which used cell fractionation and biochemical analysis to define the ordered organization of the processing of glycoproteins by the Golgi.
- Kingsley, D., K. F. Kozarsky, M. Segal, and M. Krieger. 1986a. Three types of low density lipoprotein receptor-deficient mutant have pleiotropic defects in the synthesis of N-linked, O-linked, and lipid-linked carbohydrate chains. *J. Cell Biol.* 102:1576-1585.
- Kingsley, D. M., K. F. Kozarsky, L. Hobbie, and M. Krieger. 1986c. Reversible defects in O-linked glycosylation and LDL receptor expression in a UDP-Gal/UDP-GalNAc 4-epimerase deficient mutant. *Cell* 44:749-759.
- Krieger, M., P. Reddy, K. Kozarsky, D. Kingsley, L. Hobbie, and M. Penman. 1989. Analysis of the synthesis, intracellular sorting, and function of glycoproteins using a mammalian cell mutant with reversible glycosylation defects. *Methods Cell Biol.* 32: 57-84.
- Stanley, P. 1985. Lectin-resistant glycosylation mutants. In *Molecular Cell Genetics: The Chinese Hamster Cell*. M. M. Gottesman, editor. John Wiley & Sons, Inc., New York. 745-772.

ER:

- J-X Zhang, I. Braakman, K.E.S. Matlack & A. Helenius "Quality Control in the Secretory Pathway: The role of calreticulin, calnexin and BiP in the Retention of glycoproteins with C-terminal truncations" *Mol. Biol. Cell* *:1943-1954 (1997)
- Tom A Rapoport, Melissa M Rolls and Berit Jungnickel: "Approaching the mechanism of protein transport across the ER membrane [Review article]" *Current Opinion in Cell Biology* 1996 8 : 499-504.
- Craig Hammond and Ari Helenius: Quality control in the secretory pathway [Review article] *Current Opinion in Cell Biology* 1995 7 : 523-529
- "Signal sequence recognition and protein targeting to the endoplasmic reticulum membrane" Walter, P. and Johnson, A. E. *Ann. Rev. Cell Biol.* 10: 87-120 (1994)
- Rose, J. K., and R. W. Doms. 1988. Regulation of protein export from the endoplasmic reticulum. *Ann. Rev. Cell Biol.* 4:257-288.
- "Oxidized redox state of glutathione in the endoplasmic reticulum" C. Hwang, A.J. Sinskey, H. F. Lodish (1992) *Science* 257:1496-1502.
- "Folding, Trimerization and Transport are Sequential Events in the Biogenesis of Influenza Virus Hemagglutinin" Copeland et. al. *Cell* 53:197-209.
- "Oligomerization is essential for transport of VSV G to the cell surface" T.E. Kreis and H. F. Lodish (1986) *Cell* 46: 929-937.
- "Protein disulphide isomerase: building bridges in protein folding" R. Freedman, T. Hirst and M. F. Tuite (1994) *TIBS* 19: 331-336
- "Sequential interaction of the chaperones BiP and GRP94 with immunoglobulin chains in the endoplasmic reticulum" J. Melnick, J.H. L. Dul and Y. Argon (1994) *Nature* 370: 373-375.
- "Role of ATP and disulphide bonds during protein folding in the endoplasmic reticulum" I. Braakman, J. Helenius and A. Helenius (1992) *Nature* 356: 260-262.
- "Protein folding in the cell" M-J. Gething and J. Sambrook (1992) *Nature* 355:33-45.
- "A chaperone with a sweet tooth" C. Hammond and A. Helenius (1994) *Current Biology* 3: 884-886.
- "The bonds that Tie: catalyzed disulfide bond formation" J. C. A. Bardwell and J. Beckwith (1993) *Cell* 74:769-771.
- "The emergence of the chaperone machines" C. Georgopoulos (1992) *TOBS* 17:295-299.
- "Heat shock proteins and molecular chaperones: mediators of protein conformation and turnover in the cell" E. A. Craig, J. S. Weissman, and A. L. Horwich (1994) *Cell* 78: 365-372.
- "Chaperones: Helpers along the pathways to protein folding" E. A. Craig (1993) *Science* 260: 1902-1903.
- "To fold or not to fold..." D. A. Agard (1993) *Science* 260: 1903-1904.
- 3 papers characterizing GroEL structure and function: (1994) *Science* 265:653-656; 656-659; 659-666.
- "Members of the 70 kD heat shock protein family contain a highly conserved calmodulin-binding domain" M.A. Stevenson & S. K. Calderwood (1990) *Mol. Cell. Biol.* 10:1234-1238.
- "Peptide binding and release by proteins implicated as catalysts of protein assembly" G. C. Flynn, T. G. Chappell

and J. E. Rothman (1989) *Science* **245** 385-90 - peptide-binding elicits hydrolysis and ATP hydrolysis is necessary for peptide release

"Loss of BiP/GRP78 function blocks translocation of secretory proteins in yeast" J. P. Vogel, L. M. Misra and M. D. Rose (1990) *JCB* 110: 1885-1895. KAR2 ts mutant gives accumulation of precursors on cytoplasmic side of ER.
"Tracking an elusive receptor" R.B. Kelly (1990) *Nature* 345: 480-481. KDEL receptor.-72 kD

ER & Golgi transport

Alvar Trucco, Roman S. Polishchuk, Oliviano Martella, Alessio Di Pentima, Aurora Fusella, Daniele Di Giandomenico, Enrica San Pietro, Galina V. Beznoussenko, Elena V. Polishchuk, Massimiliano Baldassarre, Roberto Buccione, Willie J. C. Geerts, Abraham J. Koster, Koert N. J. Burger, Alexander A. Mironov & Alberto Luini Secretory traffic triggers the formation of tubular continuities across Golgi sub-compartments *Nature Cell Biology* 6, 1071 - 1081 (2004)

Hee-Seok Kweon, Galina V. Beznoussenko, Massimo Micaroni, Roman S. Polishchuk, Alvar Trucco, Oliviano Martella, Daniele Di Giandomenico, Pierfrancesco Marra, Aurora Fusella, Alessio Di Pentima, Eric G. Berger, Willie J. C. Geerts, Abraham J. Koster, Koert N. J. Burger, Alberto Luini, and Alexander A. Mironov Golgi enzymes are enriched in perforated zones of Golgi cisternae but excluded from peri-Golgi vesicles. *Mol. Biol. Cell* Vol. 15, Issue 10, 4710-4724, October 2004

Oka T, Ungar D, Hughson FM, Krieger M. The COG and COPI complexes interact to control the abundance of GEARs, a subset of Golgi integral membrane proteins. *Mol Biol Cell*. 2004 May;15(5):2423-35.

P. Novick, S. Ferro and R. Schekman "Order of events in the yeast secretory pathway" *Cell* 25: 461-469 (1981). Use of yeast genetics to define critical genes and order the secretory pathway.

"The rate of bulk flow from the endoplasmic reticulum to the cell surface" F. T. Wieland, M. L. Gleason, T. A. Serafini and J. E. Rothman (1987) *Cell* **50** 289-300

The rate of Bulk flow from the Golgi to the plasma membrane" A. Karrenbauer, D. Jeckel, W. Just, R. Birk, R.R. Schmidt, J. E. Rothman, and F.T. Wieland (1990) *Cell* 63: 259-267

"A putative GTP binding protein homologous to interferon-inducible mx proteins performs an essential function in yeast protein sorting" J. H. Rothman, C.K. Raymond, T. Gilbert, P.J. O'hara and T.H. Stevens (1990) *Cell* 61:1063-1074.

Use γ SGTP to isolate rabbit liver Golgi coated transport vesicles V. Malhotra, T. Serafini, L. Orci, J. Shepherd and J. Rothman *Cell* 58:329-336 (1989), proteins: 160 kD, 94-100 kD set, 50 kD, 34&37 kD, 20-28 kD

Fatty acyl CoA hydrolysis (fatty acylation) required: N Pfanner, L. Orci, B. Glick, M. Amherdt, S. Arden, V. Malhotra, & J. Rothman *Cell* 59:95-102 (1989)

"SNAPs, a family of NSF attachment proteins involved in intracellular membrane fusion in animals and yeast" D. O. Clary, I. C. Griff and J. E. Rothman (1990) *Cell* **61** 709-21

Original Assays

E. Fries and J. E. Rothman "Transport of vesicular stomatitis virus glycoprotein in a cell-free extract" *Proc. Natl. Acad. Sci. USA* 77: 3870-3874 (1980). The beginning of the use of cell-free membrane transport assays for the biochemical analysis of membrane transport.

ER to Golgi assays: Balch: W. E. Balch, M. M. Elliott and D. S. Keller *JBC* 261 14681-14689, 1986 and W. E. Balch and D. S. Keller *JBC* 261 14690-14696 1986; *JCB* 104:749-760 1987; W. Balch, K. Wagner, D. Keller, *JCB* 104: 749-760, ER->Golgi of VSV-G using Golgi mannosidase I to monitor, requires ATP, cytosolic factors, and only works with homogenates from mitotic cells; D. Wilson, C. Wilcox, G. Flynn, E. Chen, W. Kuang, W. Henzel, M. Block, A. Ullrich, J. Rothman *Nature* 339:355-359 (1989); C. Beckers, M. Block, B. Glick, J. Rothman, W. Balch *Nature* 339:397-398

SNARES

Parlati F, Varlamov O, Paz K, McNew JA, Hurtado D, Sollner TH, Rothman JE. Distinct SNARE complexes mediating membrane fusion in Golgi transport based on combinatorial specificity. *Proc Natl Acad Sci U S A*. 2002 Apr 16;99(8):5424-9.

Fukuda R, McNew JA, Weber T, Parlati F, Engel T, Nickel W, Rothman JE, Sollner TH. Functional architecture of an intracellular membrane t-SNARE. *Nature*. 2000 Sep 14;407(6801):198-202.

Parlati F, McNew JA, Fukuda R, Miller R, Sollner TH, Rothman JE. Topological restriction of SNARE-dependent membrane fusion. *Nature*. 2000 Sep 14;407(6801):194-8.

McNew JA, Parlati F, Fukuda R, Johnston RJ, Paz K, Paumet F, Sollner TH, Rothman JE. Compartmental specificity of cellular membrane fusion encoded in SNARE proteins. *Nature*. 2000 Sep 14;407(6801):153-9.

Orci L, Amherdt M, Ravazzola M, Perrelet A, Rothman JE. Exclusion of golgi residents from transport vesicles budding from Golgi cisternae in intact cells. *J Cell Biol*. 2000 Sep 18;150(6):1263-70.

McNew JA, Weber T, Parlati F, Johnston RJ, Melia TJ, Sollner TH, Rothman JE. Close is not enough: SNARE-dependent membrane fusion requires an active mechanism that transduces force to membrane anchors. *J Cell*

Biol. 2000 Jul 10;150(1):105-17.
Weber T, Parlati F, McNew JA, Johnston RJ, Westermann B, Sollner TH, Rothman JE. SNAREpins are functionally resistant to disruption by NSF and alphaSNAP. J Cell Biol. 2000 May 29;149(5):1063-72.

Coatomer, COPI, COPII, Clathrin, etc

- Fotin A, Cheng Y, Grigorieff N, Walz T, Harrison SC, Kirchhausen T. Structure of an auxilin-bound clathrin coat and its implications for the mechanism of uncoating. *Nature*. 2004 Oct 24
- Fotin A, Cheng Y, Sliz P, Grigorieff N, Harrison SC, Kirchhausen T, Walz T. Molecular model for a complete clathrin lattice from electron cryomicroscopy. *Nature*. 2004 Oct 24
- Barlowe C, Orci L, Yeung T, Hosobuchi M, Hamamoto S, Salama N, Rexach MF, Ravazzola B, Amherdt M, Schekman R: COPII: a membrane coat formed by Sec proteins that drive vesicle budding from the endoplasmic reticulum. *Cell* 1994, 77 : 895-907.
- Cosson P, Letourneur F: Coatomer interaction with di-lysine endoplasmic reticulum retention motifs. *Science* 1994, 263 : 1629-1631.
- Letourneur F, Gaynor EC, Hennecke S, Demouliere C, Duden R, Emr SD, Riezman H, Cosson P: Coatomer is essential for retrieval of dilysine-tagged proteins to the ER. *Cell* 1994, 79 : 1199-1207.
- Duden, R., Griffiths, G., Frank, R., Argos, P., and Kreis, T. E. (1991). β -COP, a 110 kd protein associated with non-clathrin-coated vesicles and the Golgi complex, shows homology to β -adaptin. *Cell* 64, 649-665.
- Duden, R., Hosobuchi, M. Hamamoto, S., Winey, M., Byers, B. and Schekman, R. (1994) "Yeast B- and B' Coat Proteins (COP): Two coatomer subunits essential for endoplasmic reticulum to golgi protein traffic" *J. Biol. Chem.* 269: 24486-24495.
- Donaldson, J. G., Cassel, D., Kahn, R. A. and Klausner, R. D. (1992b). ADP-ribosylation factor, a small GTP-binding protein, is required for binding of the coatomer protein beta-COP to Golgi membranes. *Proc Natl Acad Sci U S A* 89, 6408-12.
- Kuge, O., Hara-Huge, S., Orci, L., Ravazzola, M., Amherdt, M., Tanigawa, G., Wieland, F. T., and Rothman, J. E. (1993). ζ -COP, a subunit of coatomer, is required for COP-coated vesicle assembly. *J. Cell Biol.* 123, 1727-1734.
- Guo, Q., E. Vasile, and M. Krieger. 1994. Disruptions in Golgi structure and membrane traffic in a conditional lethal mammalian cell mutant are corrected by ϵ -COP. *J. Cell Biol.* 125:1213-1224.
- Hosobuchi, M., Kreis, T., and Schekman, R. (1992). SEC21 is a gene required for ER to Golgi protein transport that encodes a subunit of a yeast coatomer. *Nature* 360, 603-605.
- Ostermann, J., Orci, L., Tani, K., Amherdt, M., Ravazzola, M., Elazar, Z., and Rothman, J. E. (1993). Stepwise assembly of functionally active transport vesicles. *Cell* 75, 1015-1025.
- Pepperkok, R., Scheel, J., Horstmann, H., Hauri, H. P., Griffiths, G., and Kreis, T. E. (1993). β -COP is essential for biosynthetic membrane transport from the endoplasmic reticulum to the Golgi complex in vivo. *Cell* 74, 71-82.
- Serafini, T., Stenbeck, G., Brecht, A., Lottspeich, F., Orci, L., Rothman, J. E., and Wieland, F. T. (1991). A coat subunit of Golgi-derived non-clathrin-coated vesicles with homology to the clathrin-coated vesicle coat protein beta-adaptin. *Nature* 349, 215-220.
- Stenbeck, G., Schreiner, R., Herrmann, D., Auerbach, S., Lottspeich, F., Rothman, J. E., and Wieland, F. T. (1992). γ -COP, a coat subunit of non-clathrin-coated vesicles with homology to SEC21p. *FEBS letter* 314, 195-198.
- Stenbeck, G., Harter, C., Brecht, A., Herrmann, D., Lottspeich, F., Orci, L., and Wieland, F.T. (1993) β' -COP, a novel subunit of coatomer. *EMBO J.* 12, 2841-2845.
- Waters, M. G., Serafini, T., and Rothman, J. E. (1991). 'Coatomer': a cytosolic protein complex containing subunits of non-clathrin-coated Golgi transport vesicles. *Nature* 349, 248-251.

BFA

- Donaldson, J., Finazzi, D., and Klausner, R. D. (1992a). Brefeldin A inhibits Golgi membrane-catalyzed exchange of guanine nucleotide onto ARF protein. *Nature* 360, 350-352.
- Helms, J. B., and Rothman, J. E. (1992). Inhibition by brefeldin A of a Golgi membrane enzyme that catalyses exchange of guanine nucleotide bound to ARF. *Nature* 360, 352-354.
- Klausner, R. D., J. G. Donaldson, and J. Lippincott-Schwartz. 1992. Brefeldin A: insights into the control of membrane traffic and organelle structure. *J. Cell Biol.* 116:1071-80.
- Fujiwara, T., Oda, K., Yokota, S., Takatsuki, A., and Ikebara, Y. (1988) Brefeldin A causes disassembly of the Golgi complex and accumulation of secretory proteins in the endoplasmic reticulum. *J. Biol. Chem.* 263, 18545-18552.
- Takatsuki, A., and Tamura, G., (1985). Brefeldin A, a specific inhibitor of intracellular translocation of vesicular stomatitis virus G protein: intracellular accumulation of high-mannose type G protein and inhibition of its cell surface expression. *Agric. Biol. Chem.* 49, 899-902.
- Lippincott-Schwartz, J., Donaldson, J. G., Schweizer, A., Berger, E. G., Hauri, H., Yuan, L. C., and Klausner, R. D. (1990). Microtubule-dependent retrograde transport of proteins into the ER in the presence of brefeldin A suggests an ER recycling pathway. *Cell* 60, 821-836.

- Lippincott-Schwartz, J., Yuan, L. C., Bonifacino, J. S., and Klausner, R. D. (1989). Rapid redistribution of Golgi proteins into the ER in cells treated with brefeldin A: evidence for membrane cycling from Golgi to ER. *Cell* 56, 801-813.
- Orci, L., Tagaya, M., Amherdt, M., Perrelet, A., Donaldson, J. G., Lippincott, S. J., Klausner, R. D., and Rothman, J. E. (1991). Brefeldin A, a drug that blocks secretion, prevents the assembly of non-clathrin-coated buds on Golgi cisternae. *Cell* 64, 1183-1195.
- Donaldson, J. G., Lippincott, S. J., and Klausner, R. D. (1991a). Guanine nucleotides modulate the effects of brefeldin A in semipermeable cells: regulation of the association of a 110-kD peripheral membrane protein with the Golgi apparatus. *J Cell Biol.* 112, 579-588.

GTP proteins

- Joel Moss and Martha Vaughan. Structure and Function of ARF Proteins: Activators of Cholera Toxin and Critical Components of Intracellular Vesicular Transport Processes. *J. Biol. Chem.* 1995; 270: 12327-12330.
- Melacon, P. "G whizz" *Current Biology* 3:230-233 (1993).
- M. Aridor & W. E. Balch "Timing is everything" *Nature* 383:220-221 (1996)
- V. Rybin, O. Ullrich, M. Rubino, K. Alexandrov, I. Simon, M. C. Seabra, R. Goody, M. Zerial "GTPase activity of Rab5 acts as a timer for endocytic membrane fusion" *Nature* 383: 266-269 (1996).
- Stow, J. L., de Almeida, J. B., Narula, N., Holtzman, E. J., Ercolani, L., and Ausiello, D. A. (1991). A heterotrimeric G protein, $\text{G}\alpha_i$ -3, on golgi membranes regulates the secretion of a heparan sulfate proteoglycan in LLC-PK1 epithelial cells. *J. Cell Biol.* 114, 1113-1124.
- Schwaninger, R., Plutner, H., Bokoch, G. M., and Balch, W. E. (1992). Multiple GTP-binding proteins regulate vesicular transport from the ER to Golgi membranes. *J. Cell Biol.* 119, 1077-1096.
- Pimplikar, S. W., and Simons, K. (1993). Regulation of apical transport in epithelial cells by a G_S class of heterotrimeric G protein. *Nature* 362, 456-458.
- "rab3 is a small GTP binding protein exclusively localized to synaptic vesicles" G. Fischer et al (T. Sudhof (1990) PNAS 87:1988-1992. hydrophobic modifications for membrane bound form.
- "Requirement for GTP hydrolysis in the formation of secretory vesicles" S. A. Tooze, U. Weiss and W. B. Huttner (1990) *Nature* 347:207-208. - constitutive secretory vesicles budding inhibited by GTPgammaS in vitro.
- Stenbeck, G., Harter, C., Brecht, A., Herrmann, D., Lottspeich, F., Orci, L., and Wieland, F.T. (1993) β' -COP, a novel subunit of coatomer. *EMBO J.* 12, 2841-2845.
- Wilson, B. S., Palade, G. E., and Farquhar, M. G. (1993). Endoplasmic reticulum-through-golgi transport assay based on O-glycosylation of native glycophorin in permeabilized erythroleukemia cells: role for $\text{G}\alpha_3$. *Proc. Natl. Acad. Sci. USA* 90, 1681-1685.
- Montmayeur, J-P., and Borrelli, E. (1994). Targeting of $\text{G}\alpha_2$ to the Golgi by Alternative Spliced Carboxyl-Terminal Region. *Science* 263, 95-98.
- Donaldson, J. G., Kahn, R. A., Lippincott, S. J., and Klausner, R. D. (1991b). Binding of ARF and beta-COP to Golgi membranes: possible regulation by a trimeric G protein. *Science* 254, 1197-1199.
- Bomsel, M., and Mostov, K. (1992). Role of heterotrimeric G proteins in membrane traffic. *Mol. Biol. Cell* 3, 1317-1328.

Mutants

- Yeast:** for extensive references, see Pryer, N. K., Wuestehube, L. J., and Schekman, R. (1992). Vesicle-mediated protein sorting. *Annu. Rev. Biochem.* 61, 471-516.
- P. Novick, S. Ferro and R. Schekman "Order of events in the yeast secretory pathway" *Cell* 25: 461-469 (1981). Use of yeast genetics to define critical genes and order the secretory pathway.
- "An essential role for a phospholipid transfer protein in yeast Golgi function" V.A. Bankaitis, J. R. Aitken, A.E. Cleves and W. Dowhan (1990) *Nature* 347:561-562 "Phospholipid transfer market" J.E. Rothman (1990) *Nature* 347: 519-520
- "A putative GTP binding protein homologous to interferon-inducible mx proteins performs an essential function in yeast protein sorting" J. H. Rothman, C.K. Raymond, T. Gilbert, P.J. O'hara and T.H. Stevens (1990) *Cell* 61:1063-1074.

Chinese hamster ovary (CHO) cells (mammalian):

- Ungar D, Oka T, Brittle EE, Vasile E, Lupashin VV, Chatterton JE, Heuser JE, Krieger M, Waters MG. Characterization of a mammalian Golgi-localized protein complex, COG, that is required for normal Golgi morphology and function. *J Cell Biol.* 2002 Apr 29;157(3):405-15.
- Hobbie, L., A. S. Fisher, S. Lee, A. Flint, and M. Krieger. 1994. Isolation of three classes of conditional-lethal Chinese hamster ovary cell mutants with temperature-dependent defects in LDL receptor stability and intracellular membrane transport. *J. Biol. Chem.* in press.

- Guo, Q., E. Vasile, and M. Krieger. 1994. Disruptions in Golgi structure and membrane traffic in a conditional lethal mammalian cell mutant are corrected by ϵ -COP. *J. Cell Biol.* 125:1213-1224.
- Colbaugh, P. A., Kao, C.-Y., Shia, S.-P., Stookey, M., and Draper, R. K. (1988). Three new complementation groups of temperature-sensitive Chinese hamster ovary cell mutants defective in the endocytic pathway. *Som. Cell. Mol. Genet.* 14, 499-507.
- Colbaugh, P. A., Stookey, M., and Draper, R. K. (1989). Impaired lysosomes in a temperature-sensitive mutant of Chinese hamster ovary cells. *J Cell Biol.* 108, 2211-2219.
- Kao, C.Y., and Draper, R. K. (1992). Retention of secretory proteins in an intermediate compartment and disappearance of the Golgi complex in an End4 mutant of Chinese hamster ovary cells. *J. Cell Biol.* 117, 701-715.
- Zuber, C., Roth, J., Misteli, T., Nakano, A., and Moreman, K. (1991). DS28-6, a temperature-sensitive mutant of Chinese hamster ovary cells, expresses key phenotypic changes associated with brefeldin A treatment. *Proc. Natl. Acad. Sci. USA* 88, 9818-9822.
- Roff, C. F., Fuchs, R., Mellman, I., and Robbins, A. R. (1986). Chinese hamster ovary cell mutants with temperature-sensitive defects in endocytosis. I. Loss of function on shifting to the nonpermissive temperature. *J Cell Biol.* 103, 2283- 2297.
- Robbins, A. R., Oliver, C., Bateman, J. L., Krag, S. S., Galloway, C. J., and Mellman, I. (1984). A single mutation in Chinese hamster ovary cells impairs both Golgi and endosomal functions. *J. Cell Biol.* 99, 1296-1308.
- Robbins, A. R., Peng, S. S., and Marshall., J. L. (1983). Mutant Chinese hamster ovary cells pleiotropically defective in receptor-mediated endocytosis. *J Cell Biol.* 96, 1064-1071.
- Nakano, A., Nishijima, M., Maeda, M., and Akamatsu, Y. (1985). A temperature-sensitive Chinese hamster ovary cell mutant pleiotropically defective in protein export. *Biochim. Biophys. Acta* 845, 324-332.
- Marnell, M. H., Mathis, L. S., Stookey, M., Shia, S.-P., Stone, D. K., and Draper, R. K. (1984). A Chinese hamster ovary cell mutant with a heat-sensitive, conditional-lethal defect in vacuolar function. *J. Cell Biol.* 99, 1907-1916.
- Malmstrom, K., and Krieger, M. (1991). Use of radiation suicide to isolate constitutive and temperature-sensitive conditional Chinese hamster ovary cell mutants with defects in the endocytosis of low density lipoprotein. *J. Biol. Chem.* 266, 24025-24030.
- Krieger, M., Kingsley, D. M., Sege, R., Hobbie, L., and Kozarsky, K. F. (1985). Genetic analysis of receptor-mediated endocytosis. *TIBS* 10, 447-452.
- Hughes-Ryser, J., Mandel, R., Hacobian, A., and Shen, W. C. (1988). Methotrexate-poly(lysine) as a selective agent for mutants of Chinese hamster ovary cells defective in endocytosis. *J Cell Physiol.* 135, 277-284.
- Cain, C.C., Wilson, R. B., and Murphy, R. F. (1991). Isolation by fluorescence-activated cell sorting of CHO cell lines with pleiotropic, temperature-sensitive defects in receptor recycling. *J. Biol. Chem.* 266, 11746-11752.

Endocytosis

- Christophe Lamaze and Sandra L Schmid: The emergence of clathrin-independent pinocytic pathways [Review article] *Current Opinion in Cell Biology* 1995 7 :573-580.
- Sever S. Ap-2 makes room for rivals. *Dev Cell.* 2003 Oct;5(4):530-2.
- Motley, A., Bright, N.A., Seaman, M.N., and Robinson, M.S. (2003). *J. Cell Biol.* 162, 909-918.
- Hinrichsen, L., Harborth, J., Andrees, L., Weber, K., and Ungewickell, E.J. (2003). *J. Biol. Chem.*, in press.
- Conner, S.D. and Schmid, S.L. (2003). *J. Cell Biol.* 162, 773-780.

Phospholipids etc., esp PIP

T. Martin "New directions for phosphatidylinositol transfer" *Current Biology* 5:990-992 (1995)

Lipid traffic etc.

- Lange Y, Ye J, Steck TL: Circulation of cholesterol between lysosomes and plasma membrane. *J Biol Chem* 1998, 273: 18915-18922.
- Liscum L, Munn NJ: Intracellular cholesterol transport. *Biochim Biophys Acta* 1999, 1438: 19-37.
- Lipid trafficking and sorting: how cholesterol is filling gaps Dick Hoekstra, Sven CD van Ijzendoorn *Current Opinion in Cell Biology* 2000, 12:496-502.

O-GlcNAc

- Zachara NE, Hart GW. Cell signaling, the essential role of O-GlcNAc! *Biochim Biophys Acta*. 2006 May-Jun;1761(5-6):599-617.
- Slawson C, Housley MP, Hart GW. O-GlcNAc cycling: how a single sugar post-translational modification is changing the way we think about signaling networks. *J Cell Biochem.* 2006 Jan 1;97(1):71-83.
<http://www3.interscience.wiley.com/cgi-bin/fulltext/112101836/HTMLSTART>
- Akimoto Y, Hart GW, Hirano H, Kawakami H. O-GlcNAc modification of nucleocytoplasmic proteins and diabetes. *Med Mol Morphol.* 2005 Jun;38(2):84-91
- Maeda Y, Ashida H, Kinoshita T. CHO Glycosylation Mutants: GPI Anchor. *Methods Enzymol.* 2006;416:182-205.