This Week's Citation Classic®

Keenan T W & Morre D J. Phospholipid class and fatty acid composition of Golgi apparatus isolated from rat liver and comparison with other cell factions. *Biochemistry—USA* 9:19-25, 1970; and, **Kennan T W, Morre D J & Basu S.** Ganglioside biosynthesis. Concentration of glycosphingolipid glycosyltransferases in Golgi apparatus from rat liver. *J. Biol. Chem.* 249:310-5, 1974.

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Lipid composition of Golgi apparatus purified from rat liver was determined and the results were published in the first paper. Paper two provides the first demonstration that glycosyltransferases of glycosphingolipid biosynthesis are concentrated in Golgi apparatus. [The *SCI*® indicates that these papers have been cited in more than 205 and 175 publications, respectively.]

Golgi Apparatus Lipids

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While we had laboratory facilities in neighboring buildings at Purdue, we met first in 1968 as a result of publication of a paper by S.N. Grove, C.E. Bracker, and D.J. Morre.[1] Reading this paper prompted Keenan to join with Morre in isolating Golgi apparatus from homogenates of animal tissues, using a rapid method Morre had developed for isolation of Golgi apparatus tractions in good yield and of purity sufficient for biochemical analyses.[2]

Our initial collaboration centered on the compositional basis for the polarity of Golgi apparatus observed via electron microscopy. We hypothesized that Golgi apparatus may have a membrane lipid composition intermediate between that of endoplasmic reticulum and plasma membrane. Results of our studies, published in the *Biochemistry* paper, provided evidence that Golgi apparatus were intermediate between endoplasmic reticulum and plasma membrane in relative amounts of two major membrane phospholipids—sphingomyelin and phosphatidyl choline. This paper has been cited frequently since it was one of the earliest biochemical studies of isolated Golgi apparatus. Results from this study were a key component in the formulation of the endomembrane hypothesis,[3] developed to guide our further studies in the area of Golgi apparatus function in membrane differentiation and secretion.

The second paper was an extension of our earlier study, showing that a galactosyltransferase was highly enriched in Golgi apparatus and could serve as a marker enzyme to monitor Golgi apparatus isolation.'This finding led us to question the prevailing wisdom that glycolipids were exclusively localized in, and synthesized by, plasma membrane. We showed first that sialic acid-containing glycosphingolipids (gangliosides) were not exclusively localized in plasma membrane[5] but, instead, were found also in Golgi apparatus and other intracellular membranes.[6] Our first attempts to establish the cellular localization of glycosyltransferases of ganglioside biosynthesis were limited by the necessity to synthesize some of the required sugar nucleotide substrates. We contacted Subhash Basu for assistance. He provided us with sugar nucleotides made in his laboratory and with expert advice on making transferase assays with lipid acceptors. The paper from this work is cited frequently because it provided the first evidence for a central role for Golgi apparatus in glycosphingolipid synthesis.

Not long after we published the second of these studies, Morre changed departments and, a few years later, Keenan changed institutions. Yet, we continue the collaboration which began more than 20 years ago. Recently, we worked together on reconstitution of Golgi apparatus function in a cell-free system[7] and now are engaged in collaborative studies of the role of Golgi apparatus in lipid trafficking.

1. **Grove S N, Bracker C E & Morre D J.** Cytomembrane differentiation in the endoplasmic reticulum-Golgi apparatus-vesicle complex. *Science* 161:171-3, 1968. (Cited 165 times.)
2. **Morre D J, Hamilton R J Mollenhauer H H. Mahley R W, Cunningham W P, Cheetham R D & LeQuire V S**. Isolation of a Golgi apparatus-rich fraction from rat liver. I. Method and morphology. *J. Cell Biol.* 44:484-91, 1970. (Cited 145 times.)
3. **Morre D J, Keenan T W & Mollenhauer H H.** Golgi apparatus function in membrane transformations and product compartmentalization: studies with cell fractions isolated from rat liver. (Clementi F &. Ceccarelli B, eds.) *Advances in cytopharmacology.* New York: Raven Press. 1971. Vol. 1. p. 159-82.
4. **Morre D J, Merlin L M & Keenan T W.** Localization of glycosyl transferase activities in a Golgi apparatus-rich fraction isolated from rat liver. *Biochem. Biophys. Res. Common.* 37:813-9, 1969. (Cited 185 times.)
5. **Keenan T W, Huang C M & Morre D J.** Gangliosides: nonspecific localization in the surface membranes of bovine mammary gland and rat liver. *Biochem. Biophys. Res. Commun.* 47.1277-85, 1972.
6. **Keenan T W, Morre D J & Huang C M.** Distribution of gangliosides among subcellular fractions from rat liver and bovine mammary gland. *FEBS Lett.* 24:204-8, 1972.
7. **Nowack D D, Morre D M. Paulik M, Keenan T W & Morre D J.** Intracellular membrane flow: reconstitution of transition vesicle formation and function in a cell-free system. *Proc. Nat. Acad. Sci. USA* 84:6098-102, 1987.

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