Investigation of the Effect of Sugar Stereochemistry on Biologically Relevant Lyotropic Phases from Branched-Chain Synthetic Glycolipids by Small-Angle X-ray Scattering

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Supporting Information

ABSTRACT: Synthetic branched-chain glycolipids are suitable as model systems in understanding biological cell membranes, particularly because certain natural lipids possess chain branching. Herein, four branched-chain glycopyranosides, namely, 2-hexyl-decyl-α-D-glucopyranoside (α-Glc-OC₁₀C₆), 2-hexyl-decyl-β-D-glucopyranoside (β-Glc-OC₁₀C₆), 2-hexyl-decyl-α-D-galactopyranoside (α-Gal-OC₁₀C₆), and 2-hexyl-decyl-β-D-galactopyranoside (β-Gal-OC₁₀C₆), with a total alkyl chain length of 16 carbon atoms have been synthesized, and their phase behavior has been studied. The partial binary phase diagrams of these nonionic surfactants in water were investigated by optical polarizing microscopy (OPM) and small-angle X-ray scattering (SAXS). The introduction of chain branching in the hydrocarbon chain region is shown to result in the formation of inverse structures such as inverse hexagonal and inverse bicontinuous cubic phases. A comparison of the four compounds showed that they exhibited different polymorphism, especially in the thermotropic state, as a result of contributions from anomeric and epimeric effects according to their stereochemistry. The neat α-Glc-OC₁₀C₆ compound exhibited a lamellar (Lₐ) phase whereas dry α-Gal-OC₁₀C₆ formed an inverse bicontinuous cubic Iₐ₃d (Q₃d) phase. Both β-anomers of glucoside and galactoside adopted the inverse hexagonal phase (H₃) in the dry state. Generally, in the presence of water, all four glycolipids formed inverse bicontinuous cubic Iₐ₃d (Q₃d) and Pn₃m (Q₁d) phases over wide temperature and concentration ranges. The formation of inverse nonlamellar phases by these Guerbet-branched-chain glycosides confirms their potential as materials for novel biotechnological applications such as drug delivery and crystallization of membrane proteins.

INTRODUCTION

The cell membrane is normally modeled simply as a lipid bilayer with embedded protein molecules and is assumed to be just a “nano-scale wrapper” separating the cell components from their surroundings.¹,² Recently, however, the detailed internal structure of the lipid membrane itself has been recognized as important in determining the organization, dynamics, and function of the membrane. New concepts such as lateral segregation,³ domain formation,⁴ lateral pressure,⁵ curvature, and curvature elasticity⁶ have proved important in understanding membrane stability and integrity. Lipid domain heterogeneity has been widely observed and reported for phospholipid–cholesterol systems⁷ but is relatively uncommon for glycolipid systems although water-filled defects in glycolipid bilayer sheets have been observed.⁸ In addition, the detailed structure and composition of the lipids within the bilayer, including phospholipids and numerous components such as glycolipids (GLs), have been shown to be equally important in determining biomembrane function.⁹ A holistic knowledge of these issues, however, is still patchy. Understanding the physicochemical properties of the highly complex biomembrane structure is a monumental task but may be understood piecewise by uncovering the basic self-assembly properties of the various lipidic components.

The particular lyotropic phase adopted is closely related to the average “shape” of the lipid molecules, which may be cylindrical, wedge-like, or conical in a normal (type 1) or a reversed state (type 2).¹⁰ Variations in parameters such as concentration and temperature modify this average shape and may lead to lyotropic phase transitions (e.g., the lamellar phase to other phases such as hexagonal and a whole variety of cubic structures).¹¹

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