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Effects of Nonlamellar-Prone Lipids on the ATPase Activity of SecA Bound to Model Membranes

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The effect of nonlamellar-prone lipids, diacylglycerol (DG) and phosphatidylethanolamine (PE), on the ATPase activity of SecA was examined. When *Escherichia coli* (*E. coli*) PE of the standard vesicles composed of 60 mol% of this lipid and 40 mol% of dioleoylphosphatidylglycerol (DOPG) is gradually replaced with either dioleoylglycerol (DOG) or dioeloyl PE (DOPE), the ATPase activity of SecA present together increased appreciably. On the other hand, when *E. coli* PE of the standard vesicles was replaced with DOG analogs, the SecA ATPase activity decreased slightly and when replaced with phosphatidylcholine the decrease in the ATPase activity was more appreciable. When DOPE or *E. coli* PE was added to PC vesicles, the SecA ATPase activity was enhanced only slightly suggesting that the hexagonal II structure per se is not important for the ATPase activity increase. It was observed that DOG induced phase separation of PG and the lamellar-hexagonal II (L-HII) transition temperature of vesicles decreased by about 10 C. The DOG analogs had no effect on these properties suggesting the importance of the phase separation of PG and the decrease of L-HII transition temperature of lipid bilayers to the SecA ATPase activity. The phase separation of PG by Ca^{2+} also brought about increased ATPase activity of SecA underlining the importance of phase separation of PG for the enzyme activity. The incorporation of DOG or DOPE in the vesicle also increased the amount of SecA bound to model membranes and the extent of SecA penetration into the membrane. Studies with vesicles without SecA showed increased exposure of hydrophobic acyl chains when the DOG was present. Taken together, these observations suggest that the phase separation of PG and/or the bilayer penetration of SecA are mainly responsible for the enhanced SecA/vesicle interaction with concomitant increase in SecA ATPase activity.