Organelle-Mimicking Liposome Dissociates G-quadruplexes and Facilitates Transcription

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Supplementary Table 1. Thermodynamic parameters for formation of the G-quadruplex structures by mcG_n [a]

POPC Concentration (mM)	$\Delta H°$ (kcal mol^{-1})	$T\Delta S°$ (kcal mol^{-1})	$\Delta G°_{25}$ (kcal mol^{-1})	T_m (°C)
		1cG$_2$		
0.0	–30.7 ± 0.4	–29.3 ± 0.4	–1.4 ± 0.1	38.5
2.0	–26.6 ± 0.2	–25.7 ± 0.1	–0.9 ± 0.1	33.0
		1cG$_4$		
0.0	–62.1 ± 0.4	–54.7 ± 0.3	–7.4 ± 0.1	65.5
2.0	–38.1 ± 0.7	–33.9 ± 0.7	–4.2 ± 0.1	59.5
		2cG$_3$		
0.0	–43.1 ± 0.1	–40.2 ± 0.1	–2.9 ± 0.1	46.0
2.0	–27.8 ± 0.4	–26.4 ± 0.4	–1.4 ± 0.1	40.5
		3cG$_3$		
0.0	–40.2 ± 0.4	–37.9 ± 0.3	–2.3 ± 0.1	42.0
2.0	–31.7 ± 0.3	–30.3 ± 0.4	–1.4 ± 0.1	38.0
		4cG$_3$		
0.0	–43.3 ± 0.7	–41.1 ± 0.6	–2.2 ± 0.2	40.0
2.0	–33.1 ± 0.5	–31.8 ± 0.6	–1.3 ± 0.2	36.0

[a]All experiments were carried out in a buffer containing 10 mM sodium phosphate (pH 7.0), 10 mM NaCl, and 1 mM Na_2EDTA without or with 2.0 mM POPC. Values are means ± standard deviations from three independent measurements. Melting temperatures were measured at a total strand concentration of 20 μM.

Supplementary Table 2. Changes in thermodynamic parameters for formation of G-quadruplex by $1cG_n$ (n = 2, 3, and 4) in the presence of 2.0 mM POPC relative to its absence

G-quadruplex	$\Delta\Delta H°$ (kcal mol^{-1})	$\Delta(T\Delta S°)$ (kcal mol^{-1})	$\Delta\Delta G°_{25}$ (kcal mol^{-1})
$1cG_2$	+4.1	+3.6	+0.5
$1cG_3$	+17.9	+16.0	+1.9
$1cG_4$	+24.0	+20.8	+3.2

Supplementary Table 3. Thermodynamic parameters for the formation of G-quadruplex structure by $1crG_3$[a]

POPC Concentration (mM)	$\Delta H°$ (kcal mol^{-1})	$T\Delta S°$ (kcal mol^{-1})	$\Delta G°_{25}$ (kcal mol^{-1})	T_m (°C)
0.0	–45.8± 0.5	–40.6 ± 0.6	–5.2 ± 0.1	62.5
2.0	–23.5 ± 0.4	–22.0 ± 0.3	–1.5 ± 0.1	54.5

[a]All experiments were carried out in a buffer containing 10 mM sodium phosphate (pH 7.0), 10 mM NaCl, and 1 mM Na_2EDTA without or with 2.0 mM POPC. Values are means ± standard deviations from three independent measurements. Melting temperatures were measured at a total strand concentration of 20 μM.

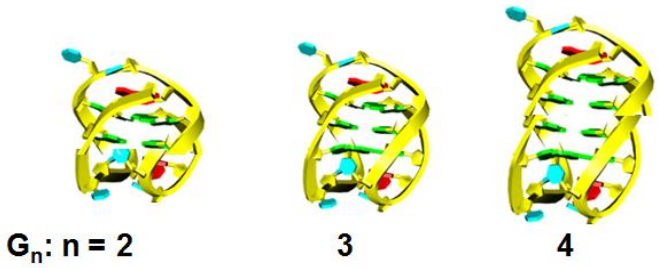
Supplementary Table 4. Thermodynamic parameters for the formation of G-quadruplex structure by $1cG_3$[a]

Liposome (2.0 mM)	$\Delta H°$ (kcal mol^{-1})	$T\Delta S°$ (kcal mol^{-1})	$\Delta G°_{25}$ (kcal mol^{-1})	T_m (°C)
–	-40.0 ± 0.6	-36.9 ± 0.5	-3.1 ± 0.1	50.0
IM	-28.0 ± 0.5	-26.0 ± 0.4	-2.0 ± 0.1	47.0
NM	-24.9 ± 0.8	-23.4 ± 0.3	-1.5 ± 0.1	45.0
ER	-23.1 ± 0.3	-21.7 ± 0.2	-1.4 ± 0.1	42.5

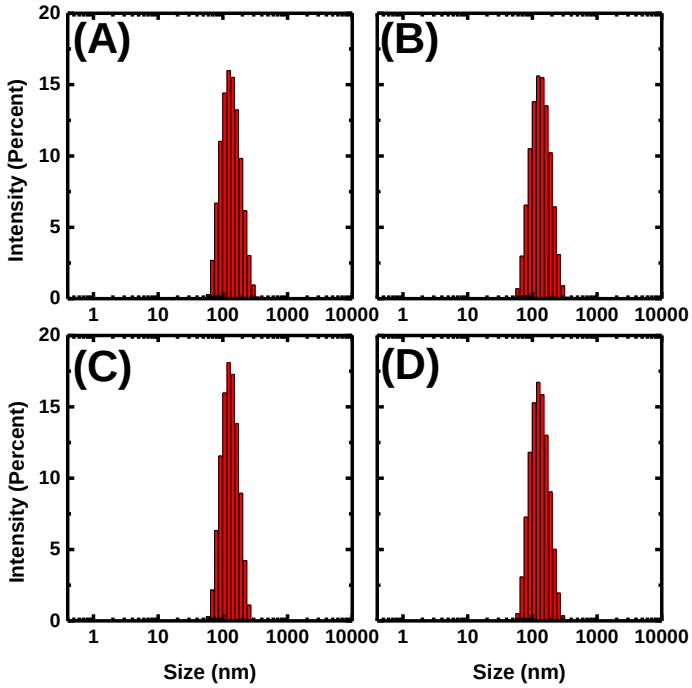
[a]All experiments were carried out in a buffer containing 10 mM sodium phosphate (pH 7.0), 10 mM NaCl, and 1 mM Na_2EDTA without or with 2.0 mM liposome. Values are means ± standard deviations from three independent measurements. Melting temperatures were measured at a total strand concentration of 20 μM.

Supplementary Table 5. Changes of thermodynamic parameters of G-quadruplex formed by $1cG_3$ in the presence of IM, NM, and ER mimicking liposomes and POPC liposomes

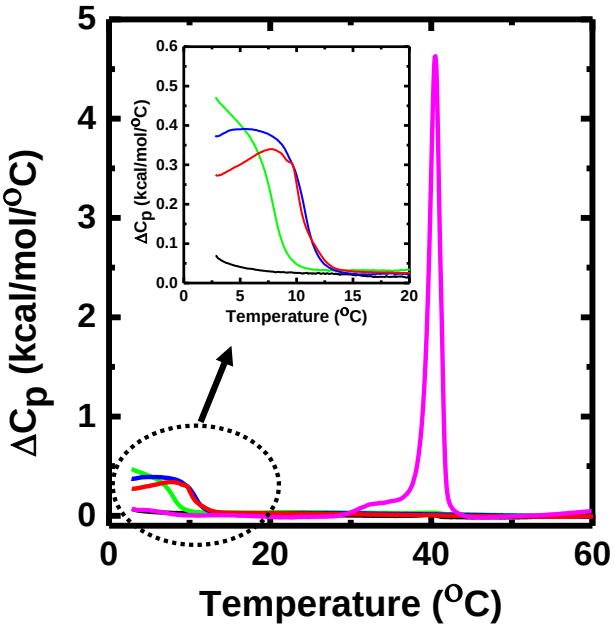
Liposome (2.0 mM)	**Molar ratio of POPC (%)**	**$\Delta\Delta H°$ (kcal mol^{-1})**	**$\Delta(T\Delta S°)$ (kcal mol^{-1})**	**$\Delta\Delta G°_{25}$ (kcal mol^{-1})**
IM	43	+12.0	+10.9	+1.1
NM	69	+15.1	+13.5	+1.6
ER	75	+16.9	+15.2	+1.7
POPC	100	+17.9	+16.0	+1.9



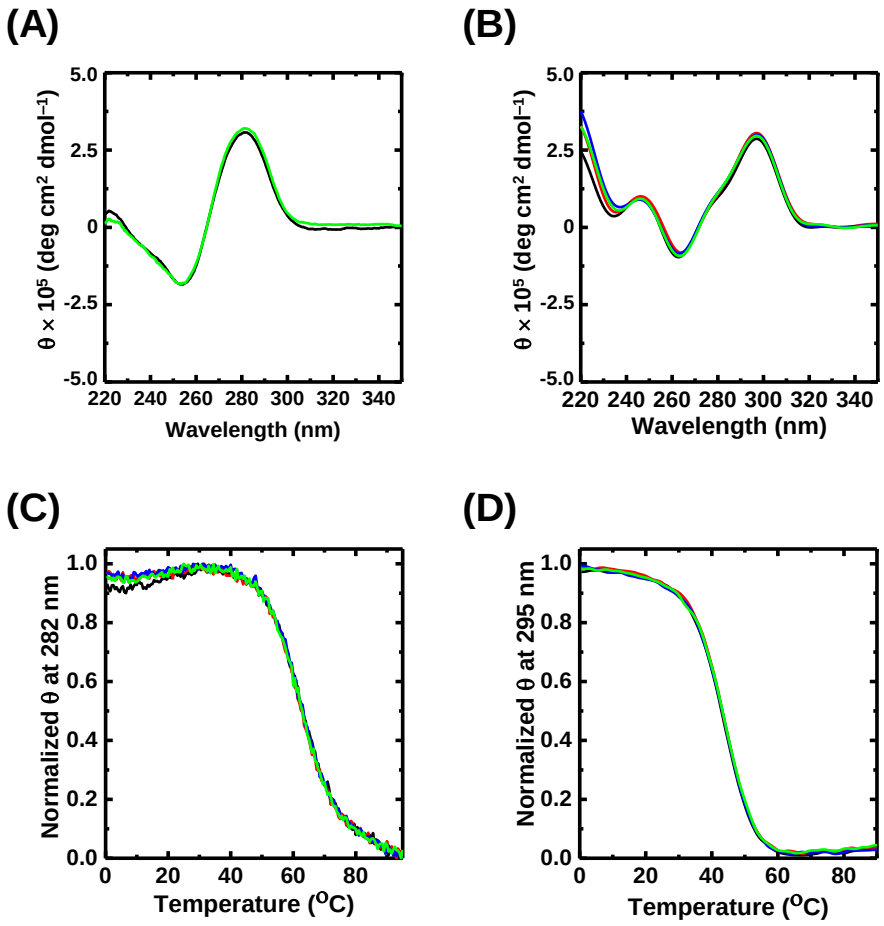
Supplementary Figure 1. Schematic representations of G_n (n = 2, 3, and 4) structures.



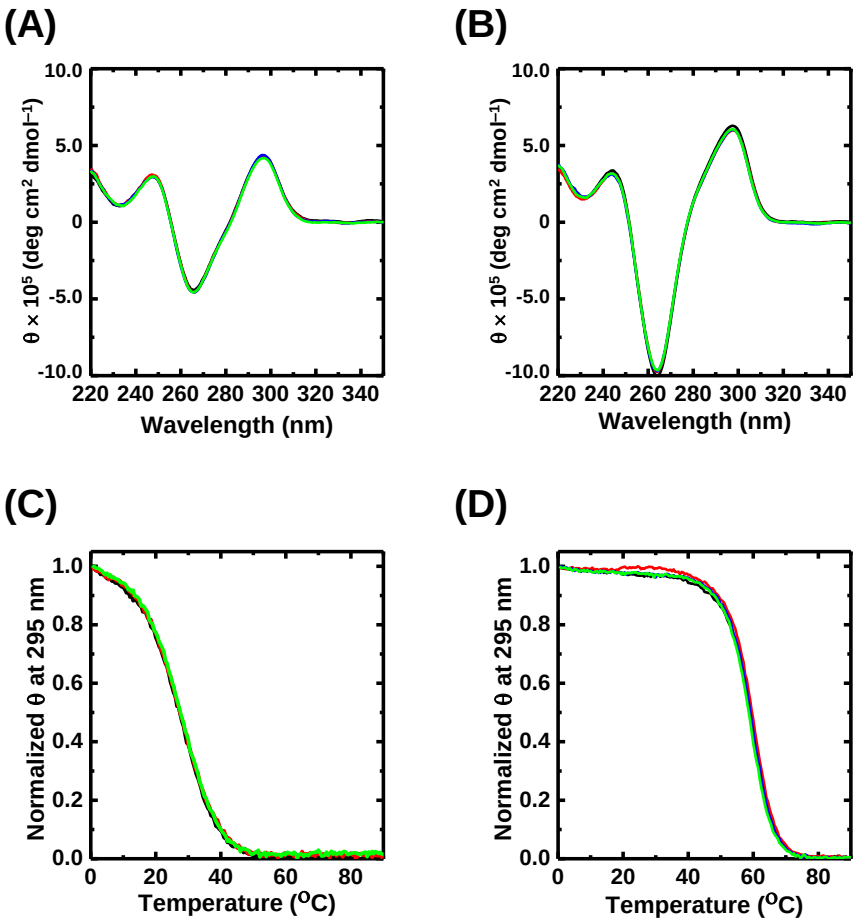
Supplementary Figure 2. Diameter distributions of **(A)** POPC, **(B)** IM, **(C)** NM, and **(D)** ER liposomes at 25 °C.



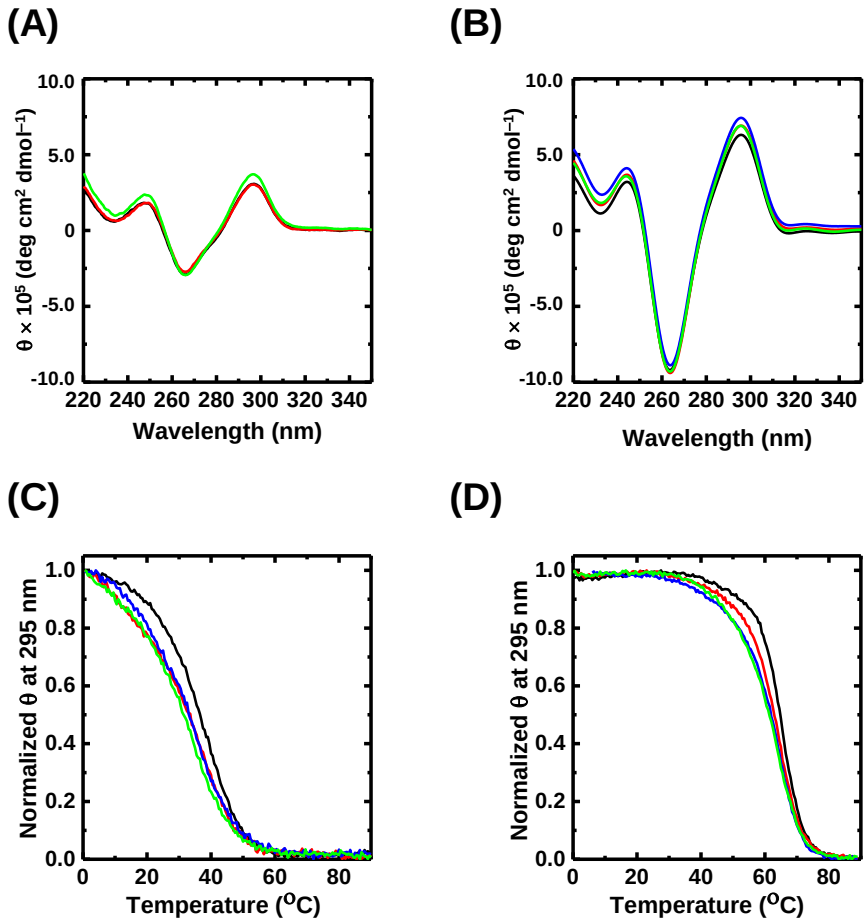
Supplementary Figure 3. DSC heating thermograms for POPC (black), IM (red), NM (blue), ER (green), and DPPC (pink) liposomes. The inset shows DSC profiles in the region from 0 to 20 °C.



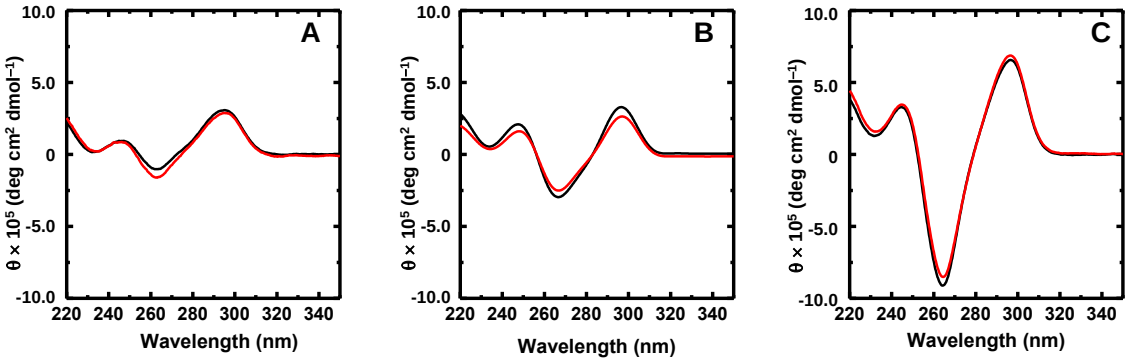
Supplementary Figure 4. CD spectra of 20 μM **(A)** D and **(B)** G_3 at 4 °C and normalized CD melting profiles of **(C)** D at 282 nm and **(D)** G_3 at 295 nm in the absence (black) and presence of 2.0 mM IM (red), NM (blue), and ER (green) liposomes.



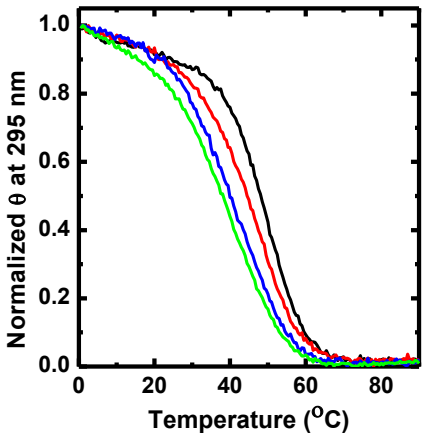
Supplementary Figure 5. CD spectra of 20 μM **(A)** G_2 and **(B)** G_4 at 4 °C and normalized CD melting profiles of **(C)** G_2 and **(D)** G_4 at 295 nm in the absence (black) and presence of 2.0 mM IM (red), NM (blue), and ER (green) liposomes.



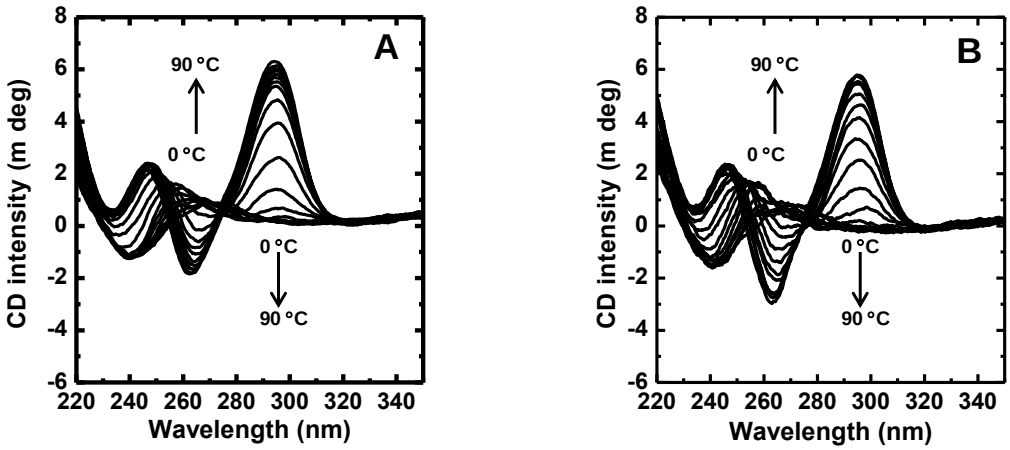
Supplementary Figure 6. CD spectra of 20 μM **(A)** $1cG_2$ and **(B)** $1cG_4$ at 4 °C and normalized CD melting profiles of **(C)** $1cG_2$ and **(D)** $1cG_4$ at 295 nm in the absence (black) and presence of 2.0 mM IM (red), NM (blue), and ER (green) liposomes.



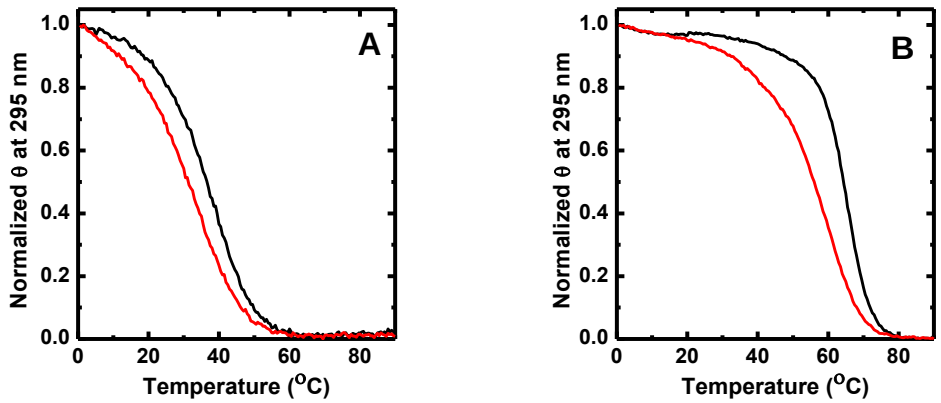
Supplementary Figure 7. CD spectra of 20 μM **(A)** 1cG$_3$, **(B)** 1cG$_2$, and **(C)** 1cG$_4$ in the absence (black) and presence (red) of 2.0 mM POPC liposomes at 4 °C.



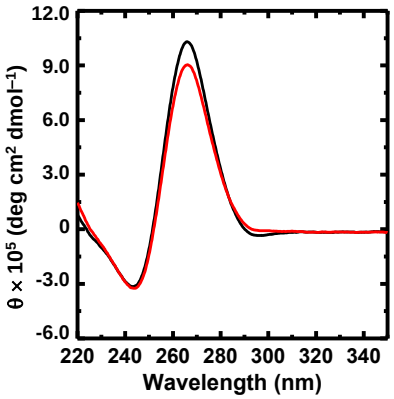
Supplementary Figure 8. Normalized CD melting profiles at 295 nm of 20 μM total strand concentration of $1cG_3$ in the absence (black) and presence of 0.5 (red), 1.0 (blue), and 2.0 mM (green) POPC liposomes.



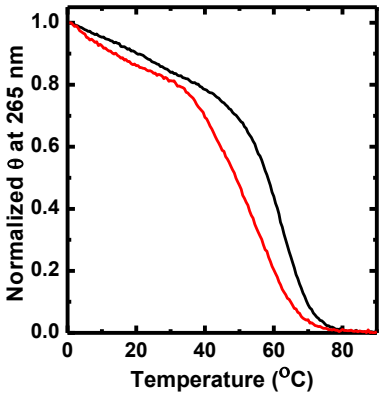
Supplementary Figure 9. CD spectra of 20 μM $1cG_3$ in **(A)** the absence and **(B)** presence of 2.0 mM POPC liposomes at temperatures from 0 to 90 °C.



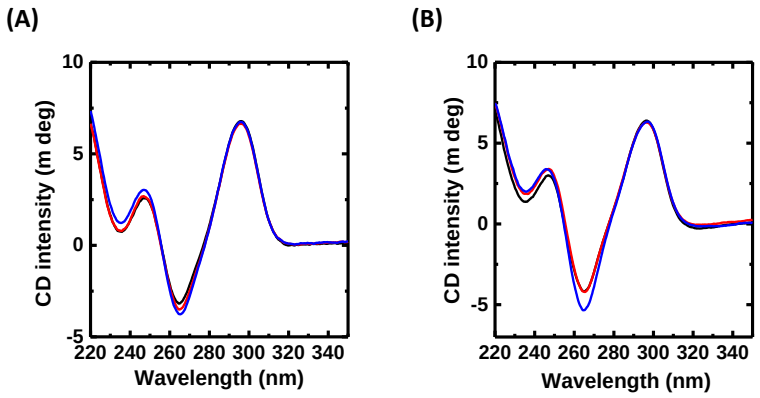
Supplementary Figure 10. Normalized CD melting profiles at 295 nm of 20 μM total strand concentration of **(A)** $1cG_2$ and **(B)** $1cG_4$ in the absence (black) and presence (red) of 2.0 mM POPC liposomes.



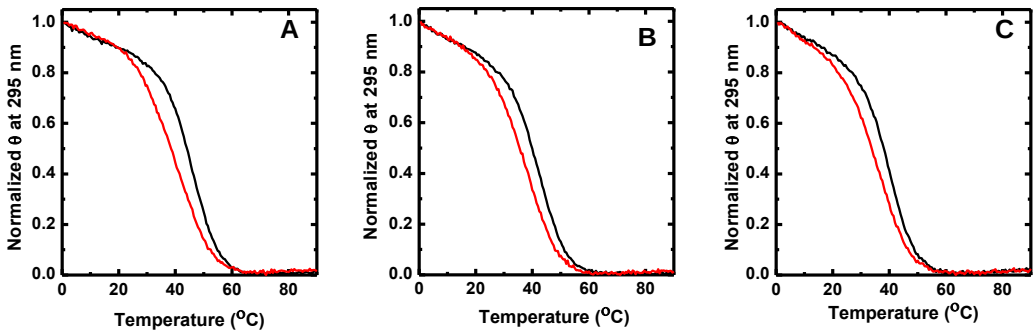
Supplementary Figure 11. CD spectra of 20 μM 1crG$_3$ in the absence (black) and presence (red) of 2 mM POPC liposomes at 4 °C.



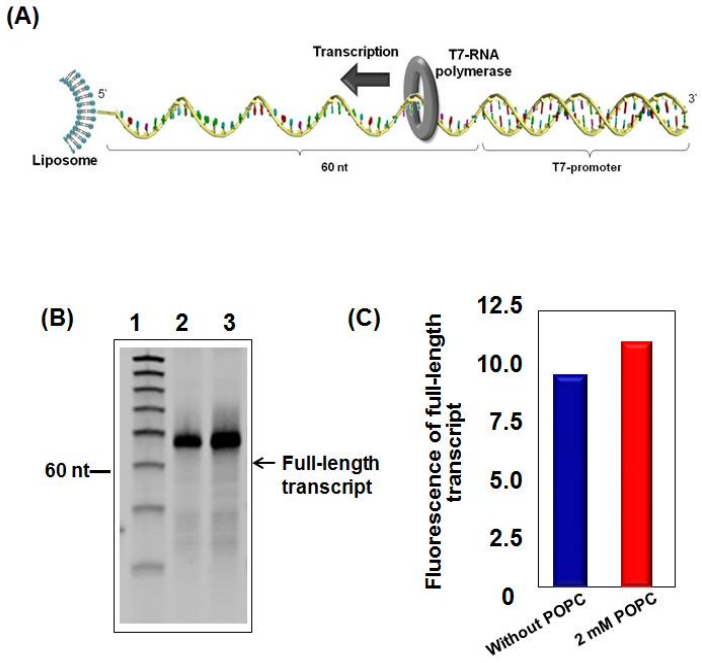
Supplementary Figure 12. Normalized CD melting profiles at 265 nm of 20 μM total strand concentration of 1crG$_3$ in the absence (black) and presence (red) of 2.0 mM POPC liposomes.



Supplementary Figure 13. CD spectra of 20 μM $2cG_3$ (black), $3cG_3$ (red), and $4cG_3$ (blue) in **(A)** absence and **(B)** presence of 2.0 mM POPC liposomes at 4 °C.



Supplementary Figure 14. Normalized CD melting profiles at 295 nm of 20 μM total strand concentration of **(A)** $2cG_3$, **(B)** $3cG_3$, and **(C)** $4cG_3$ in the absence (black) and presence (red) of 2.0 mM POPC liposomes.



Supplementary Figure 15. Effects of membrane surface on transcription of a linear template DNA sequence. **(A)** Illustration of the template DNA immobilized on a liposome. **(B)** Denaturing gel electrophoresis of products of transcription reactions performed for 90 min at 37 °C. Reaction mixtures contained 0.3 μM T7 polymerase and 1.5 μM DNA template in a buffer containing 10 mM NaCl, 40 mM Tris-HCl (pH 8.0), 8 mM $MgCl_2$ and 2 mM spermidine in the absence and presence of 2.0 mM POPC. Lane 1, size marker; lane 2, transcription products in the absence of POPC; lane 3, transcription products in the presence of 2.0 mM POPC. **(C)** Comparison of fluorescence intensities of full-length transcripts from gel bands in panel **B**.