

### Supplementary Information

Molecular dynamics simulation movies.

**Movie\_S1:** MD simulation for a single component vesicle at  $R_{h/t} = 1.0$ ,  $\Delta a_0^s = 1.74$ , and  $\nu = 0.77$  in Figure 2c. The single component vesicle was composed of the cylinder shaped lipids displayed by blue/green (Figure 1). Water beads are not displayed for clarity. The simulation time was  $6,000\tau$ . During the long time simulation, the stalk was stable.

**Movie\_S2:** MD simulation for a binary vesicle division at  $R_{h/t} = 0.67$ ,  $\Delta a_0^b = 1.63$ , and  $\nu = 0.77$  in Figure 3 and Figure 5(a). The cylinder and inverse-cone shaped lipids are displayed by blue/green and cyan/red, respectively (Figure 1). Water beads are not displayed for clarity. The simulation time was about  $4,000\tau$ . The stalk was broken at about  $3,800\tau$ .