

Supplementary Information for: Directed tubule growth from giant unilamellar vesicles in a thermal gradient

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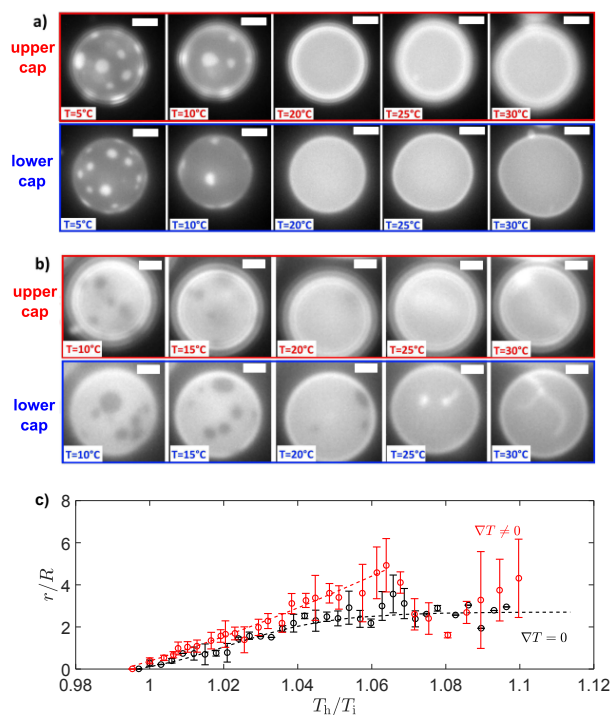


Fig. S1 When $\nabla T = 0$, tubules grow above the transition temperature, T_t , from either side of the vesicle. a) For GUVs initially exhibiting L_d circular domains, tubules grow externally from any point on the membrane after T_t is exceeded. DOPE:DOPC:DPPC:chol (6:21.5:27.5:45 mol%) is shown as an example. Scale bars are $10\ \mu\text{m}$. Above $298\ \text{K}$ the GUV becomes more flaccid and begins to grow a tubule at $303\ \text{K}$ ($T_t \simeq 288\ \text{K}$). b) For L_o circular domains, tubules grow internally e.g. DOPE:DOPC:DPPC:chol (6:29:35:30 mol%). c) Tubule length, r , with GUV radius, R , increases sigmoidally with temperature for GUVs with composition DOPE:DOPC:DPPC:chol (2:33:35:30 mol%) and $\nabla T = 0$. Error bars are standard errors on the mean.

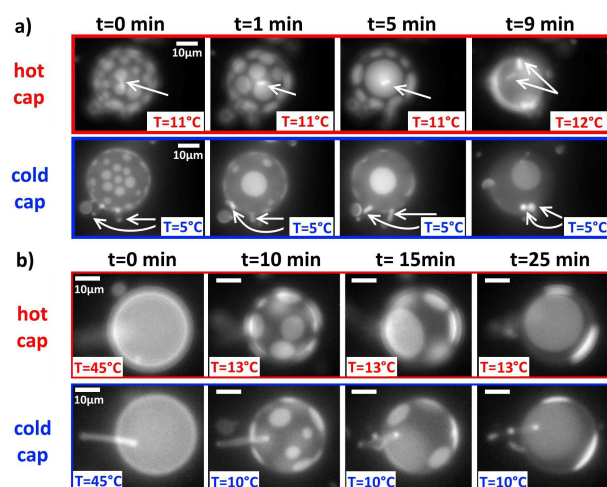


Fig. S2 Tubule growth before domain migration is complete does not give directed growth. Examples are shown for GUVs with a composition of DOPE:DOPC:DPPC:chol (4:23.5:27.5:45 mol%). a) Tubules grow from the L_d domains during the migration stage before domains reach the hot cap. Complete depletion of the cold cap is needed to ensure tubule growth is only from the hot side. Arrows indicate the position of the tubules. b) A tubule grows from the cold side of a GUV above T_l with $\Delta T = 0$. On quenching below T_l domains form. When a thermal gradient is applied, domains migrate to the hot side, but the tubes do not. Scale bars are 10 μm .

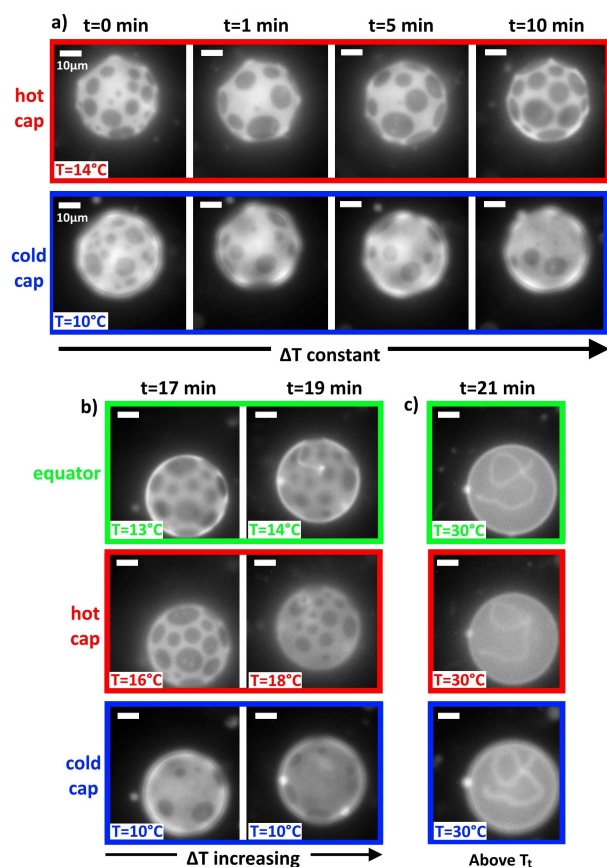


Fig. S3 For GUVs with L_o circular domains, tubule growth is internal and is not directed by a thermal gradient. a) L_o domains on a GUV of DOPE:DOPC:DPPC:chol (6:29:35:30 mol%) migrate in a thermal gradient towards the hot cap. b) On increasing the temperature gradient, tubules grow internal to the vesicle (see equatorial slice). c) Raising the entire vesicle above the transition temperature retains interior tubule growth. Scale bars are $10\mu\text{m}$.

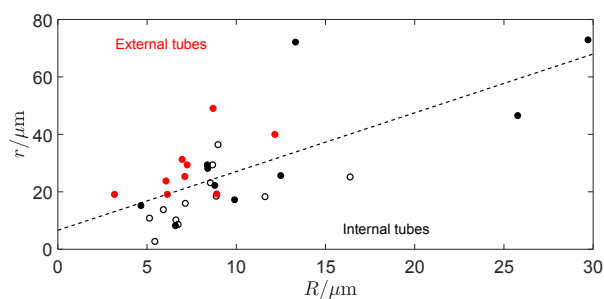


Fig. S4 External tubules grow to longer lengths, r , than internal tubes, compared to the GUV radius, R . Tubule length correlates positively with GUV radius with/without a thermal gradient (closed/open circles respectively).