S1. CALCULATION OF INCLINATION ANGLE AND DEFORMATION PARAMETER

The shape and orientation of the three-dimensional vesicles are obtained via eigenvalues of the inertia matrix. Let $\Omega^-$ be the region enclosed by the vesicle membrane. The inertia matrix is given by

$$ I_0 = \begin{bmatrix} \int_{\Omega^-} \hat{y}^2 + \hat{z}^2 \, dV & -\int_{\Omega^-} \hat{x}\hat{y} \, dV & -\int_{\Omega^-} \hat{x}\hat{z} \, dV \\ -\int_{\Omega^-} \hat{x}\hat{y} \, dV & \int_{\Omega^-} \hat{x}^2 + \hat{z}^2 \, dV & -\int_{\Omega^-} \hat{y}\hat{z} \, dV \\ -\int_{\Omega^-} \hat{x}\hat{z} \, dV & -\int_{\Omega^-} \hat{y}\hat{z} \, dV & \int_{\Omega^-} \hat{x}^2 + \hat{y}^2 \, dV \end{bmatrix}, \quad (S1) $$

where $\hat{x} = x - \bar{x}$, $\hat{y} = y - \bar{y}$, and $\hat{z} = z - \bar{z}$. The center of the vesicle, $(\bar{x}, \bar{y}, \bar{z})$ is defined as

$$ \bar{x} = \frac{1}{V} \int_{\Omega^-} x \, dV, \quad \bar{y} = \frac{1}{V} \int_{\Omega^-} y \, dV, \quad \bar{z} = \frac{1}{V} \int_{\Omega^-} z \, dV, \quad (S2) $$

while the volume is given by $V = \int_{\Omega^-} dV$. In all cases the integrals are calculated using a numeric Heaviside function and the level-set describing the interface:

$$ \int_{\Omega^-} f \, dV \approx \sum_{ijk} (1 - H(\phi_{ijk})) f_{ijk} h_x h_y h_z, \quad (S3) $$

where $f_{ijk}$ is the value of the function to be integrated at a grid point, $h_x$, $h_y$, and $h_z$ are the grid spacings in the $x$, $y$, and $z$ directions, respectively, and $H(\phi)$ is the Heaviside function [1].

The symmetric matrix $I_0$ has three real eigenvalues and orthogonal eigenvectors [2]. The inclination angle is defined as the angle between the eigenvector corresponding to the largest eigenvalue and the $x$–axis. Following the definition of deformation parameter, or asphericity, is defined as $[3, 4]$

$$ D = \frac{\lambda_{\text{max}} - \lambda_{\text{min}}}{\lambda_{\text{max}} + \lambda_{\text{min}}}, \quad (S4) $$

where $\lambda_{\text{max}}$ is the largest eigenvalue while $\lambda_{\text{min}}$ is the smallest eigenvalue.
S2. DESCRIPTION OF MOVIES

There are four movies included in this work. Each corresponds to a result presented in the main text and all have $\bar{c} = 0.4$. The movies include are:

TABLE S1: Table of movies

<table>
<thead>
<tr>
<th>File Name</th>
<th>Main Text Figure</th>
<th>$\alpha$</th>
<th>$\kappa_c^{\beta}$</th>
<th>Pe</th>
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<td>FIG2Movie.mov</td>
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<td>1.0</td>
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<tr>
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<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
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