Chapter 6

6.1) The filament density can be found using:

molecular mass of each actin monomer →

$$42 \frac{\text{KDa}}{\text{monomer}} \times 370 \frac{\text{monomer}}{\mu m} \times 1.66 \times 10^{-27} \frac{kg}{Da} \times 5 \frac{\mu m}{\text{filament}} = 12,9 \times 10^{-20} \frac{kg}{\text{filament}}$$

$$3 \frac{kg}{m^3} \times \frac{1}{12.9 \times 10^{-20}} \frac{\text{filament}}{kg} = 0,23 \times 10^{20} \frac{\text{filament}}{m^3}$$

nomial value of $\rho k_B T$ is then found to be: $0,23 \times 10^{20} \times 300 \times 1.38 \times 10^{-23} = 0,095 \frac{J}{m^3}$

b) equation D.35 states $\frac{1}{\beta K_V} = \frac{\langle (\Delta V)^2 \rangle}{V_0}$

$$\frac{\langle \Delta V^2 \rangle^{1/2}}{V} = \left(\frac{1}{\beta K_V}\right)^{1/2} \times \frac{1}{V^{1/2}} = \rho^{-1/2} \times V^{-1/2} = \left(\frac{4}{3}\pi (5 \times 10^{-6})^3\right)^{-1/2} \times \rho^{-1/2} = 0,07$$

6.2) The persistence length of the peptide can be found from

$$\langle r_{ee}^2 \rangle = 2 \xi_p L_c \longrightarrow \xi_p = \frac{\langle r_{ee}^2 \rangle}{2 L_c} = 0,21 \text{ nm}$$

and spring constant K_{sp} from:

$$K_{sp} = \frac{3 k_B T}{2 \xi_p L_c} = \frac{3 \times 1.38 \times 10^{-23} \times 300}{2 \times 0,21 \times 10^{-9} \times 4 \times 10^{-9}} = 7.4 \times 10^{-3} \frac{J}{m^2}$$

b) $K_V = \frac{K_{sp}}{8b} = \frac{7.4 \times 10^{-3}}{8 \times 10^{-9}} = 9.25 \times 10^{5} \, J/m^3$

c) The bond density is $\rho = \frac{3}{2a^2 b}$ so the value of $\rho k_B T = 36.7 \times 10^{5} \frac{J}{m^3}$

compare →

3D

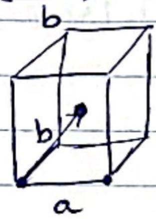
6.4) simple cubic $\rightarrow$ $\rho^* = \frac{2d}{Z} = 1 \rightarrow Z = 6$

body - centered cubic $\rho^* = \frac{3}{4} \rightarrow Z = 8$

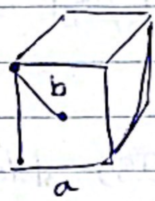
face - centered cubic $\rho^* = \frac{1}{2} \rightarrow Z = 12$

for simple cubic $\rightarrow V = b^3$

for body centric



$\frac{\sqrt{3}}{2} a = b \rightarrow V = \frac{2^3}{3\sqrt{3}} b^3$



$\frac{\sqrt{2}}{2} a = b \rightarrow V = \frac{b^3}{2\sqrt{2}}$

6.5) The consentration of filaments in the system is : $\rho = 1600 \pm 600 \ \frac{\text{filamnt}}{\mu m^3}$

$= 1.6 \pm 6 \times 10^{20} \ \frac{\text{filamnt}}{m^3}$

$D_{f\,actin} = 8nm \quad L_c = 1\mu m$

$\rightarrow$ Then transition number densities for rigid rods is

$\rho^* \sim L_c^{-3} = 10^{18} \qquad \rho^{**} \sim (D_f L_c^2)^{-1} \approx 10^{20} \times 1.25$

So the system may be isotropic or nematic since the concentration of filaments is in fact far above ρ^{**}, so they could be in a nematic phase

b) assuming the thermal energy of each particle to be $\frac{3}{2} k_B T$, for this concentration the pressure is found to be :

$P = 9.94 \times 10^{-20} \ \frac{J}{m^3}$

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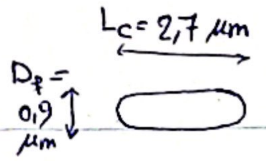
6.6) 

The densities are evaluated to be $\rho^{*} = L_c^{-3} = 5,1 \times 10^{16}$ ~~20~~ $\frac{\text{bacteria}}{m^3}$

$$\rho^{**} = (D_f L_c^2)^{-1} = 15,2 \times 10^{16} \ \frac{\text{bacteria}}{m^3}$$

b) onsager's condition for the existence of a nematic phase is that $\frac{L_c}{D_f} \gtrsim 3$ and this condition is met here.

6.7) onsager's condition : $\frac{L_c}{D_f} \gtrsim 3$

$$\frac{L_c}{D_f} = \frac{260 \text{ nm}}{18 \text{ nm}} \gg 3 \ \checkmark \ \text{satisfies}$$

b.) $\rho^{*} = L_c^{-3} = 5,7 \times 10^{19} \ \frac{\text{virus}}{m^3}$

$$\rho^{**} = (L_c^2 D_f)^{-1} = 1.07 \times 10^{21} \ \frac{\text{virus}}{m^3}$$

$$\rho_N = \frac{4.25}{D_f L_c^2} = 4.55 \times 10^{21} \ \frac{\text{virus}}{m^3}$$

to find the concentrations we must find the mass of each virus:

$\rightarrow \lambda_e \left[\frac{\text{mass}}{\text{length}}\right] = 140,000$

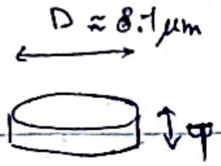
mass of each virus is then found to be: $\lambda_e \left[\frac{\text{mass}}{\text{length}}\right] \times$ length of virus = mass of virus

$\rightarrow \lambda_e \times L = 140000 \times 260 \times 10^{-9} = 364 \times 10^{-4} \ \frac{\text{mass}}{\text{virus}}$

$\rightarrow c^{*} = 2,07 \times 10^{18} \ \frac{kg}{m^3}$ or $\frac{mg}{ml}$

$\rightarrow c^{**} = 3,9 \times 10^{19} \ \frac{kg}{m^3}$ or $\frac{mg}{ml}$

$c_N = 1,66 \times 10^{20} \ \frac{kg}{m^3}$ or $\frac{mg}{ml}$



6.8)

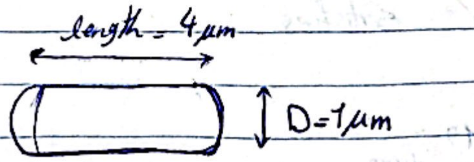
$$140\,\mu m^3 = T \times \pi \left(\frac{D}{2}\right)^2 \Rightarrow T = \frac{140}{\pi (4.05)^2} = 2.72\,\mu m$$

$$\frac{T}{D} = \frac{2.72}{8.1} = 0{,}36 > 0{,}2 \checkmark \rightarrow$$ The disks can form ordered phases

b) approx concentration : $5{,}4 \times 10^{6} \frac{cell}{mL} \times 10^{9} = 5{,}4 \times 10^{15} \frac{cell}{m^3}$

$$\frac{4}{D^3} = \frac{4}{(8.1)^3 \times 10^{-18}} = 7.5 \times 10^{15} \frac{cont}{m^3}$$

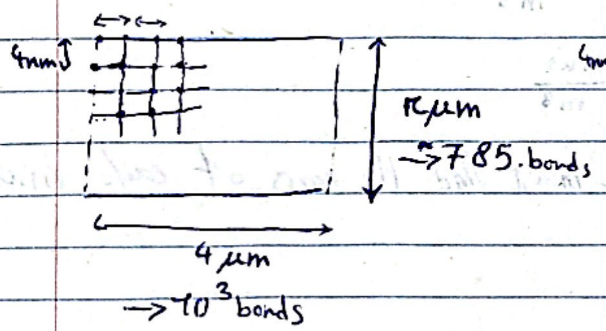
ρ is not greater than ~~7.5~~ $\frac{4}{D^3}$, so the condition for ordered phase is not met.

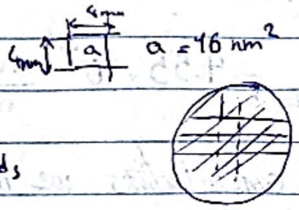


6.9)

four-fold network & b = 4nm

to find the total number of bonds on the surface of this bacterium





$$\left(2A = 2 \times \frac{\pi R^2 \times 4}{2} = 4\pi R^2\right)/a = \frac{2\pi \times 10^{-12}}{16 \times 10^{-18}} = 4.2 \times 10^{5}$$

the approximate number of bonds is around $7.86 \times 10^{5} + 4.2 \times 10^{5}$

$$= 8.25 \times 10^{5}$$

So we need 8.25×10^{5} bond $\times \frac{1}{6.022 \times 10^{23}} = 1.4 \times 10^{-18}$ mole of this drug

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6.10) $\Delta U = -\pi a^2 \sigma^2 / Y$ for a crack of length $2a$

critical stress for fracture

$$\sigma_c \sim (2Y\gamma_s / \pi a)^{1/2} \longrightarrow \Delta U = \frac{-\cancel{\pi} \times a^{\cancel{2}} \times (2\cancel{Y}\gamma_s)}{\cancel{Y} \times \cancel{\pi} \cancel{a}} = -2a\gamma_s$$

$$\sigma_c = \left(\frac{2\times 10^{9} \times 5 \times 10^{-2}}{\pi \times 10^{-8}} \right)^{1/2} = (0{,}32 \times 10^{16})^{1/2} = 0{,}56 \times 10^{8}$$

J/m