Phys 150 HW 2 solutions ①

2.1 Θεὸς ἀεὶ γεωμετρεῖ "God always geometrizes"

γεωμετρεῖ = geometry

Any answer with the word "geometry" is given full credit

2.2 Not shown in solutions → print 3 pictures of protein molecular structure; provide which molecular visualization software used

Approximate size of each protein (using webmol measurement feature)

(a) thrombin ~ 50 $\AA^3$

(b) insulin ~$(25)^2 \times 40$ $\AA^3$

(c) myosin ~$(50)^2 \times 150$ $\AA^3$

(d) actin - myosin complex ~~50 × 100 Å~~

(e) rhinovirus ~ 50·50 × 100 $\AA^3$

(f) myoglobin ~ 20 · 40 · 40 $\AA^3$

(g) DNA polymerase 40 · 40 · 130 $\AA^3$

(h) nucleosame 50 · 80 · 80 $\AA^3$

2.3 Not shown in solutions: print 2 pictures of nucleic acid molecular structures; provide software name

2.5 Size of micelle ~ 5 nm

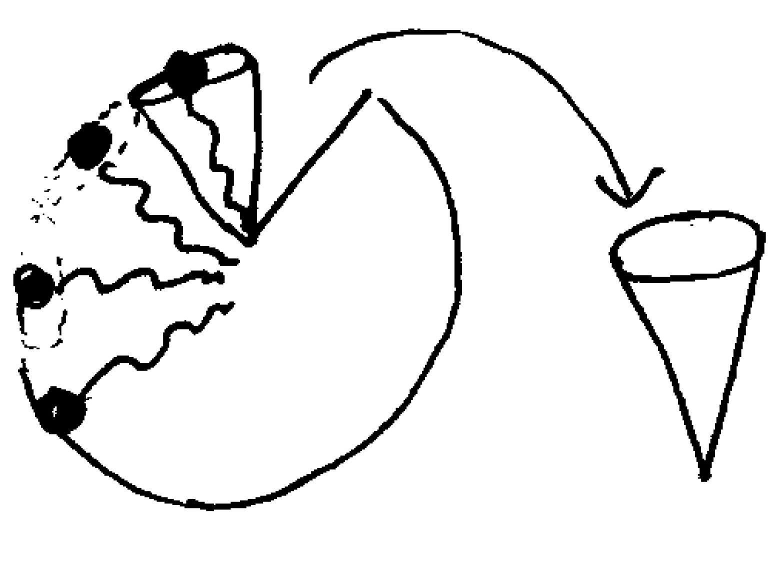
We can approximate a micelle to be a solid sphere and a bilayer to be a planar slab. We can identify three differences between the surfactants that form micelles and the phospholipids that form bilayers by considering what 3-D shapes ~~can~~ pack into these structures.

Note: Both surfactants and phospholipids consist of two parts, (1) a <u>polar</u> "head group" (2) a <u>non polar</u> "tail"

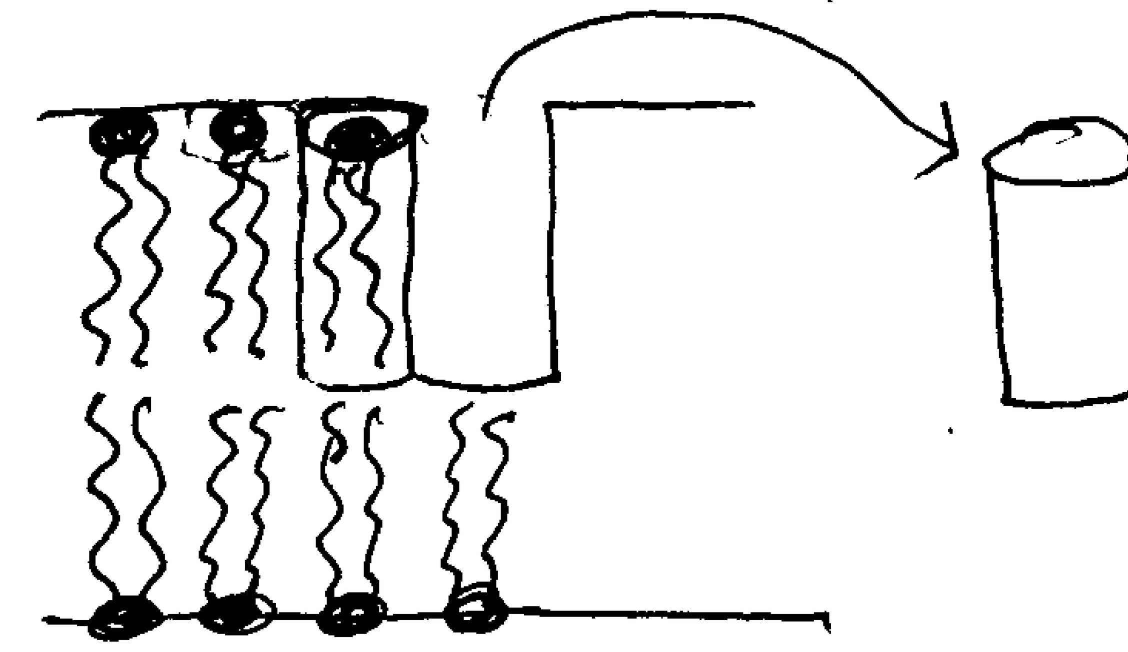
Both can have one or two tails. Both can form micelles or bilayers.

We have a goal: Identify why some of these molecules prefer to assemble into bilayers while others prefer to assemble into micelles. This is while in water with no oil present.

2.5 continued

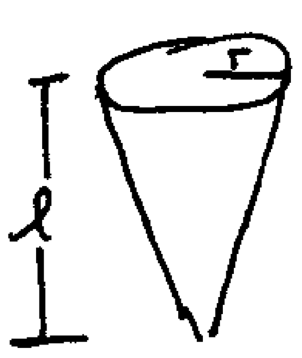


cones will pack into solid spherical structures like micelles

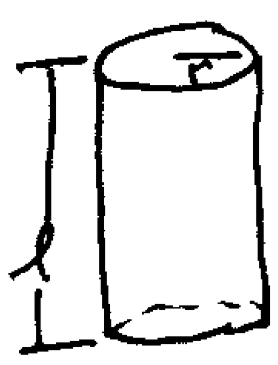


cylinders will pack into planar slabs like bilayers

What are the only things that we know about the cone and the cylinder?
Given a radius, r, and a length, l, we know the volume, v.



$v = \frac{1}{3}\pi r^2 l$



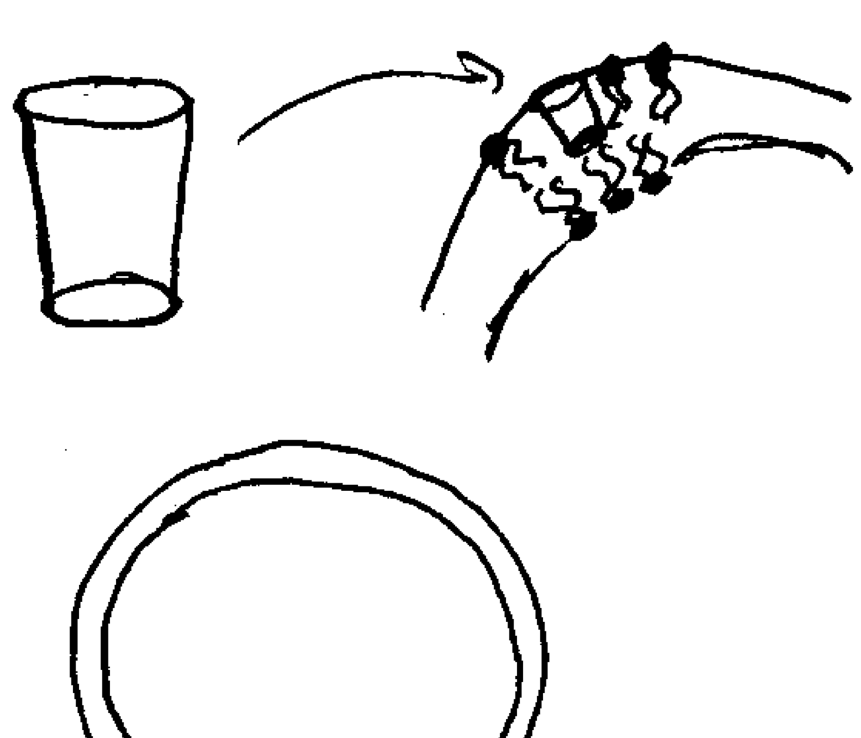
$v = \pi r^2 l$

call $\pi r^2 = a$, the head group area
l the chain length (carbon chain that makes up the tail)
v the tail volume

Then, if $\frac{v}{al} < \frac{1}{3}$, the molecule will form a micelle
Usually these are short single chained surfactants with large head group areas

$\frac{v}{al} \approx 1$, the molecule will form a planar bilayer
Usually these are long, double-chained phospholipids with small head group areas

Think: What structure would prefer to form if the lipid is $\frac{1}{3} < \frac{v}{al} < 1$?



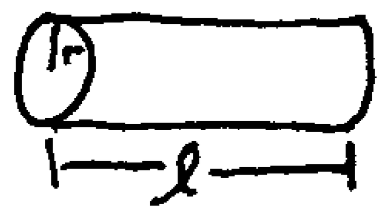
This lipid would prefer to form a slab-like structure that has some intrinsic curvature. These are called flexible bilayers. In aqueous solution, the bilayer "edge" is an unfavorable structure, so these usually close up into spherical shells. The bilayer shells are called vesicles.

For more information on surfactant and phospholipid self-assembly into structures see

Israelachvili, J. (1992) Intermolecular and Surface Forces, Academic Press

C2.7 (a) 10^{11} bacteria in 100 mg. Estimate dimensions of one bacterium assuming $\rho_{bac} = \rho_{H_2O} = 1\frac{g}{cm^3}$ and cylindrical shape with a length ~2 diameters.

What is the volume of one bacterium?



$$\ell = 2d = 4r \quad \Rightarrow \quad V = (\pi r^2)(4r) = 4\pi r^3$$

Then we can set the volume of one bacterium (from the volume of 10^{11} bacteria divided by 10^{11}) equal to $4\pi r^3$ and solve for r.

$$V_{bac} = 4\pi r^3 \quad \Rightarrow \quad r = \left(\frac{V_{bac}}{4\pi}\right)^{1/3}$$

$$= \left[\frac{1}{4\pi} \cdot \underbrace{0.1g \cdot \frac{cm^3}{1g}}_{\text{volume of } 10^{11} \text{ bacteria}} \cdot \frac{1}{10^{11}}\right]^{1/3} \approx 0.4 \cdot 10^{-4}\, cm \approx 0.4 \cdot 10^{-6}\, m = \boxed{0.4\, \mu m}$$

Then the bacterium is about $0.4\,\mu m$ in radius and about $1.7\,\mu m$ long.

(b) About 55% of the dried lump is protein; the dried lump is 30mg
Each protein is ~ 40 000 $\frac{g}{mol}$

How many proteins in <u>one</u> bacterium?

$$0.55 \cdot \frac{30 \cdot 10^{-3} g}{10^{11} \text{ bacteria}} \cdot \frac{\text{mol protein}}{4 \cdot 10^4 g} \cdot \frac{6.02 \cdot 10^{23} \text{ proteins}}{\text{mol protein}} \sim \frac{16}{4} \cdot 6 \cdot 10^{-3} \cdot 10^{-15} \cdot 10^{23} \sim \boxed{2.4 \cdot 10^6 \frac{\text{proteins}}{\text{bacterium}}}$$

<u>4 units</u>

C2.6 Brome Mosiac virus protein: using measurement tool of pymol ~ 6 nm across
the hook structure is ~6nm by itself – about
the same size as the entire protein without the hook.

4 units continued

C2.8 Given the average molecular mass of a chromosome, the average nucleotide basepair, an average protein, and an average amino acid, estimate the number of separate protein encoding genes in the chromosome.

To solve this we assume that all of the base pairs encode for amino acids and each protein is encoded for on a separate region of the chromosome (ie. no bp encodes for more than one amino acid)

Then the number of separate protein encoding genes is basically the number of basepairs in a chromosome divided by the number of amino acids in the average protein.

Some of you might know that there are 3 basepairs for each amino acid. I will use this fact here, but it is not necessary to receive full credit. If you assume that there is one bp that represents each AA, this is fine — just make it clear in your solution.

→ However, you might think that it is odd that 4 basepairs could encode for 20 something amino acids without having more than one bp/AA. How many bp do you need to distinctly encode for ~20 AA?

chromosome (C) $\sim 1.3\cdot10^9 \frac{g}{mol}$, protein (P) $\sim 3.5\cdot10^4 \frac{g}{mol}$, nucleotide base pair (bp) $\sim 618 \frac{g}{mol}$, amino acid (AA) $\sim 110 \frac{g}{mol}$

$$\underbrace{\frac{1.3\cdot10^9\,g}{mol\ C}\cdot\frac{mol\ bp}{618\,g}}_{\frac{\#\ bp}{chromosome}}\cdot\underbrace{\frac{mol\ P}{3.5\cdot10^4\,g}\cdot\frac{110\,g}{mol\ AA}}_{\frac{1}{\#AA/protein}}\cdot\frac{mol\ AA}{3\ mol\ bp}\cdot\frac{1\ mol\ gene}{1\ mol\ P}\sim\boxed{2.2\cdot10^3\ \frac{genes}{chromosome}}$$

↑ each AA is encoded by 3bp

↑ each protein is encoded by 1 gene