Question 4: The genome of *Vibrio cholera* is 4.03 Mbp. How many genes does it contain?

$\langle L_{Protein} \rangle = 300$ aa

$\langle L_{Gene} \rangle \simeq 1000 \text{ bp} = 300 \text{aa} \cdot \frac{3 \text{ bp}}{\text{a.a.}}$

Assume: genome is packed with genes

$$N_{genes} = \frac{L_{genome}}{L_{gene}} = \frac{4 \cdot 10^6 \text{ bp}}{10^3 \text{ bp}} = 4{,}000 \text{ genes}$$

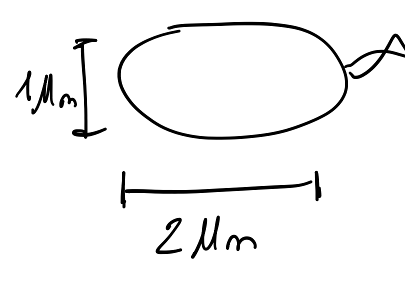
Question 3: How Many Sugar Transporters Are Needed to Make A Bacterium?

$$\#\text{ of sugar transporters} = \underbrace{\frac{\#\text{ sugars to make a cell}}{\text{cell cycle time}}}_{\text{rate of intake of sugar necessary}} \cdot \frac{1}{\underbrace{\text{transport rate of one sugar transporter}}_{\text{rate of intake of an individual transporter}}}$$

Main challenge: how many sugars to make a cell?

Assume: main component is proteins
↳ calculate how many sugars to put together all proteins

What is the protein mass of E. coli?



⇓

$1 \mu m \Rightarrow V_{Ecoli} = 1 \mu m^3$

Guided struggle:

What is the concentration of a single molecule in E. coli in molar

$V_{Ecoli} = 1 \mu m^3 = 1 \text{ fL}$

$$\frac{1 \text{ molec}}{1 \text{ fL}} = \frac{1 \text{ molec} \cdot \frac{1 \text{ mol}}{6 \cdot 10^{23} \text{ molec}}}{10^{-15} \text{ L}} = \frac{1}{6} \cdot \frac{1 \text{ mol}}{10^8 \text{ L}}$$

$$\simeq 0.16 \cdot 10^{-8} \frac{\text{mol}}{\text{L}} = 10^{-9} \text{ M} = 1 \text{ nM}$$

$m_{Ecoli} = \rho_{E.coli} \cdot V_{Ecoli}$

$= 1 \text{ kg/L} \cdot 10^{-15} \text{ L} = 10^{-15} \text{ kg}$

$= 10^{-12} \text{ g} = 1 \text{ pg}$

$m_{dry} = \frac{1}{3} \cdot m_{Ecoli} = \frac{1}{3} \text{ pg}$

$m_{Prot} \simeq \frac{1}{2} m_{dry} \simeq \frac{1}{6} \text{ pg}$

How many proteins is this?

mass of 1 prot $\simeq 30$ kDa

$$N_{Prot} = \frac{m_{Prot}}{m_{1 Prot}} = \frac{1/6 \text{ pg}}{30 \text{ kDa}} =$$

$$= \frac{1}{6} \cdot \frac{1}{30} \frac{\text{pg}}{10^3 \text{ Da}} = \frac{1}{180 \cdot 10^3} \text{ pg} \frac{1}{1\text{g}/6 \cdot 10^{23}}$$

What's 1 Da: $1 \text{ Da} = \frac{1 \text{g}}{\text{mole}} = \frac{1 \text{g}}{6 \cdot 10^{23} \text{ molec}}$

$$N_{Prot} = \frac{1}{180 \cdot 10^3} \cdot \frac{\text{pg} \cdot 6 \cdot 10^{23}}{\text{g}} =$$

$$= \frac{1}{~~180~~ \cdot ~~10^3~~} \cdot \frac{~~10^{-12}~~ ~~\text{g}~~ \cdot ~~6~~ \cdot 10^{~~23~~ ~~11~~ 8}}{~~\text{g}~~}$$
(30)

$$= \frac{1}{30} \cdot 10^8 = \frac{1}{3} \cdot 10^7 = 3 \cdot 10^6 \text{ proteins}$$

How many glucose molecules (or C atoms) are needed to make $3 \cdot 10^6$ proteins?

5 C atoms per a.a.

$N_{aa} = 300 \frac{\text{aa}}{\text{protein}} \cdot 3 \cdot 10^6 \text{ proteins} \simeq 10^9 \text{ a.a.}$

⇒ $5 \cdot 10^9$ C atoms to make a new cell

6 C / glucose

⇒ 10^9 glucose molecules to make a cell

$$\text{rate of glucose uptake} = \frac{10^9 \text{ glucose}}{20 \text{ min} \cdot 60 \text{ s/min}} = \frac{10^9 \text{ glucose}}{12 \cdot 10^2 \text{ s}}$$

$$= 10^6 \text{ glucose/s}$$

PtsI transport rate $= 200 \frac{\text{glucose}}{\text{s}}$

$$N_{PtsI} = \frac{10^6 \text{ glucose/s}}{200 \text{ glucose/s}} = \frac{1}{2} \cdot 10^4 = 5000$$

Question 8: Number of livestock on earth?
Specifically, mass of cows relative to humans?

Use Little's theorem to estimate the number of cows

$$\#\text{ of cows butchered per year} = \frac{\#\text{ cows}}{\text{age of cow @ butchering}}$$

⇓

$$\#\text{cows} = \#\text{ of cows butchered per year} \cdot \underbrace{\text{age of cow @ butchering}}_{\text{few years}}$$

\# of cows butchered per year = m beef per person per year · # people eating beef / m cow (how to estimate)

$1 \text{ kg/week/person} \cdot 10^9 \text{ beef eaters} / 1000 \text{ kg}$

$$\frac{1 \text{ kg}}{\text{week} \cdot \text{person}} \cdot 10^9 \text{ person} \frac{1}{1000 \text{ kg}}$$

$$= 10^6 \frac{\text{cows}}{\text{week}} \cdot \frac{1}{50} \frac{\text{year}}{\text{week}} = 50 \cdot 10^6 \text{ cows/year}$$

$$\Rightarrow \#\text{ cows} = \underbrace{50 \cdot 10^6 \frac{\text{cows}}{\text{year}}}_{\text{consumption rate}} \cdot \underbrace{\text{few years}}_{\text{age @ consumption}}$$

$$= 150 \cdot 10^6 \text{ cows}$$

$$\simeq 10^8 \text{ cows} \Rightarrow m_{cows} = 10^8 \text{ cows} \cdot 10^3 \text{ kg/cow}$$

$$= 10^{11} \text{ kg}$$

$$m_{Humans} = 7 \cdot 10^9 \text{ people } \frac{100 \text{ kg}}{\text{person}} = 7 \cdot 10^{11} \text{ kg}$$

$$\simeq 10^{12} \text{ kg}$$

Aside: geometric mean for estimates

$$\text{Diam St Peters} = \sqrt{d_{low} \, d_{high}}$$
(10 m, 100 m)

$$= \sqrt{10^3 \text{ m}^2}$$

$$= 10 \text{ m} \cdot \sqrt{10}$$

$$\simeq 30 \text{ m}$$

$$m_{cow} = \sqrt{m_{low} \, m_{high}}$$

$$= \sqrt{\text{few } 100 \text{ kg} \cdot \text{few} \cdot 1000 \text{ kg}}$$

$$= \sqrt{10 \cdot 10^5} \text{ kg}$$

$$= 10^3 \text{ kg}$$