Cell is the basic structural and functional unit of life

Minimal functions of a cell

Metabolism

Ability or the process to consume nutrients from the environment and convert them into energy via arrays of chemical reactions

Replication

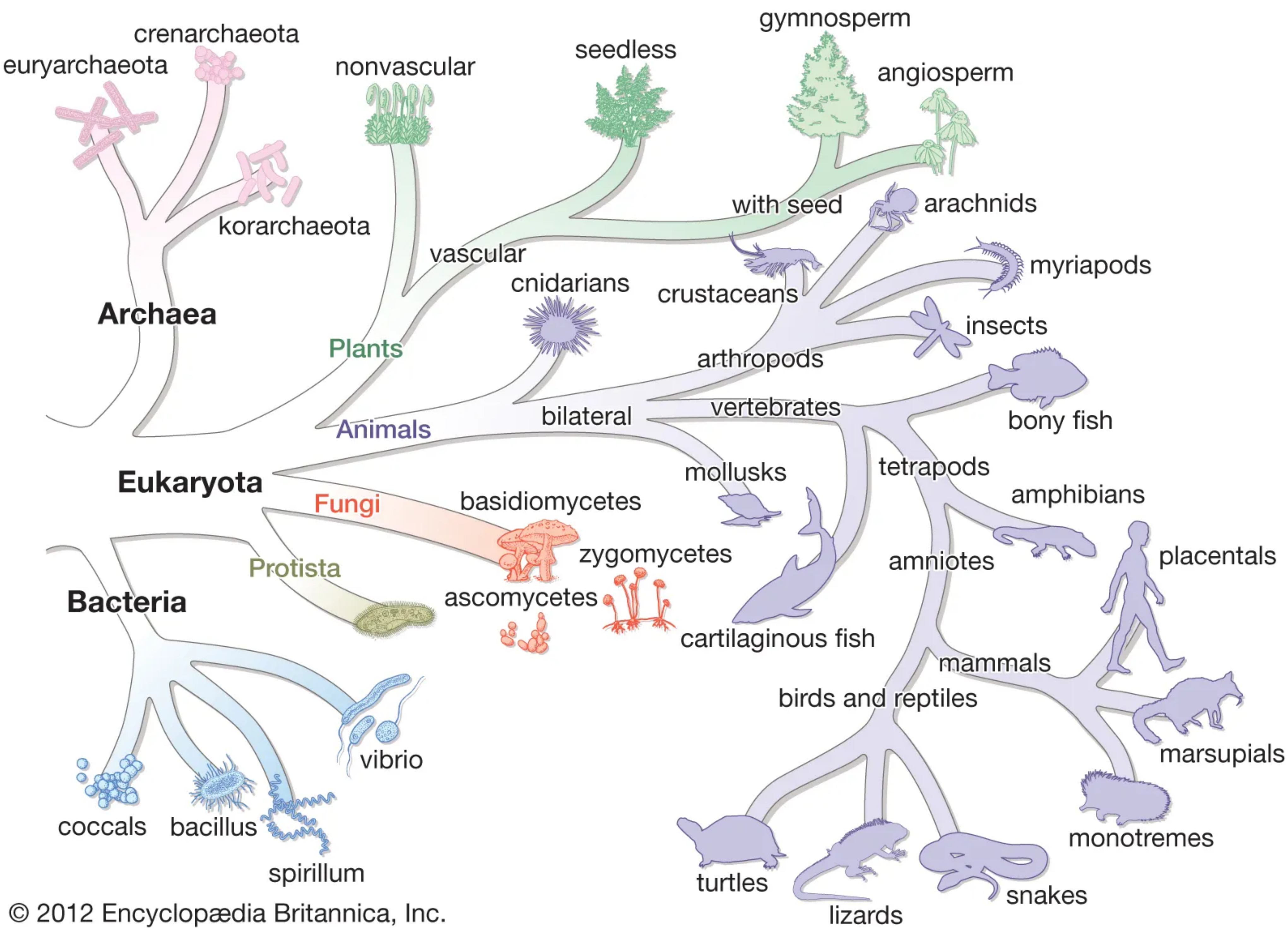
Ability or the process of creating offspring that resemble the original cell

Cell is the smallest unit of replication

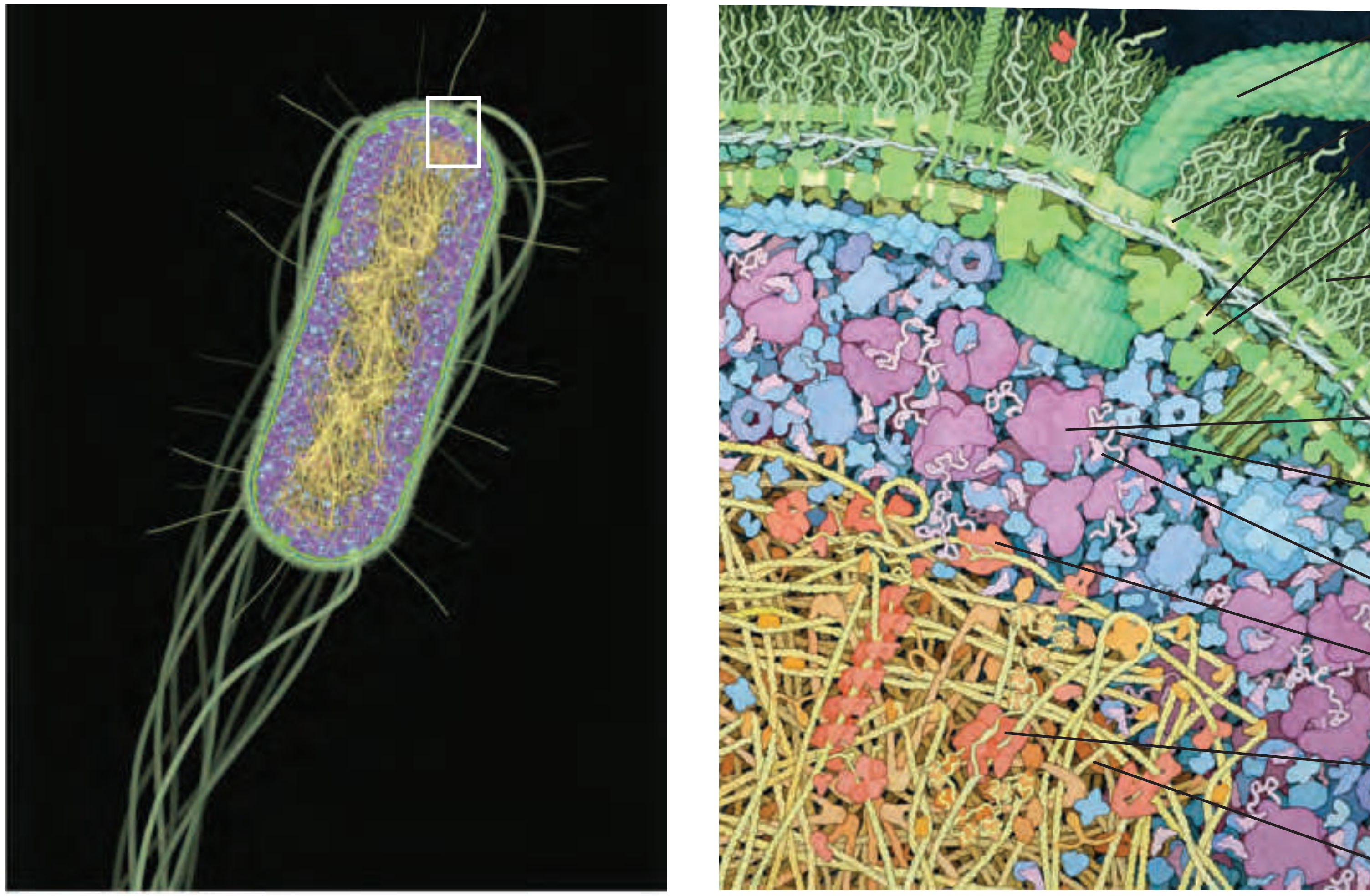
How about viruses, they also replicate!

Viruses need host cells to replicate, so cell wins

Diversity of Cells in the living world



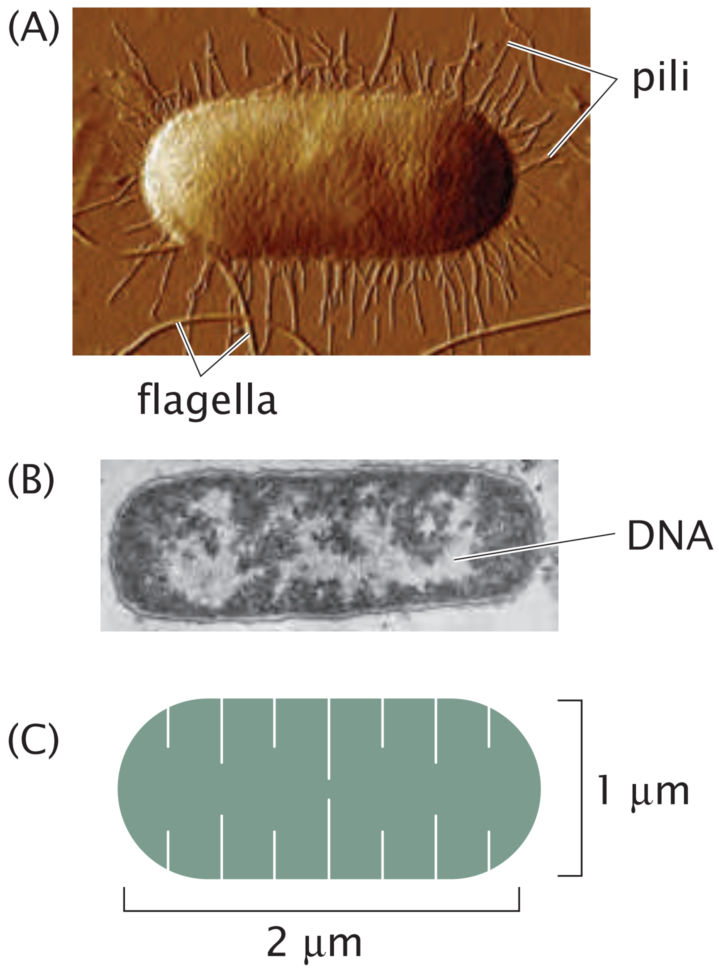
Structure of a prokaryotic cell



Key things to consider

- Bacteria may be primitive but they are still quite complex
- Number of molecules is huge! A census is an absolute necessity.
- Cell is so crowded! Space between the proteins is ~ size of the proteins
- Molecular crowding can be a regulatory factor for the cellular functions

Molecular census of *E. coli*



Lets assume the volume of an E. coli cell $\sim 1\ \mu m^3 \ \approx 1\ fL$

What can be an approximate mass of E. coli?

Assuming the cell is mostly water and water density = $1\ \ g/mL$

So, the approximate mass of E. coli = volume x density = $1\ pg$

Acc to experiments, the dry mass of E. coli is ~ 30%

If half of that is protein then protein mass in E. coli is = $0.15\ pg$

Let's now try to estimate the number of proteins in E. coli cell

Molecular census of *E. coli ….contd*

Let's assume the proteins in E. coli has a mean length of 300 amino acids

What is the mass of an amino acid molecule? $\approx \; 100 \; Da$

What is the mass of single protein molecule of $= 3 \times 10^4 \; Da \;\; \approx 5 \times 10^{-20} \; g \; (1 \; Da = 1.66 \times 10^{-24} \; g)$

Then, number of proteins in E. coli cell = $\dfrac{\text{total protein mass}}{\text{single protein mass}} = \dfrac{0.15 \times 10^{-12} \; g}{5 \times 10^{-20} \; g} = 3 \times 10^6$

Given three more info we can estimate the number of ribosomes in E. coli

- Each ribosome is $\approx 2.5 \times 10^6 \; Da$
- Only 1/3-rd of a ribosome by mass are proteins
- About 20% of all proteins are ribosomal

Then, number of ribosomes in E. coli cell $= \dfrac{0.2 \times 0.15 \times 10^{-12} \; g}{0.833 \times 10^6 \; Da} \approx 20000$

Molecular census of *E. coli* ….*contd*

Let's now estimate the number of lipids

Important info to keep in mind

- Bacteria has two bilayer membranes - inner and outer
- About half of each membrane is occupied by lipids
- Each lipid has an area $\approx 0.5\ nm^2$
- Area of E. Coli cell $\approx 6\ \mu m^2$ (assuming cubic volume)

Then, number of lipids in E-coli cell =

$$\frac{\text{total lipid surface area}}{\text{single lipid area}} = \frac{4 \times 0.5 \times A_{E.coli}}{A_{lipid}} \approx \frac{4 \times 0.5 \times 6 \times 10^{-12}}{0.5 \times 10^{-18}} \approx 2 \times 10^{7}$$

The number of water molecules in E-coli cell $= \dfrac{\text{total water mass}}{\text{single water mass}}$

$$= \frac{0.7 \times 10^{-12}\ g}{18\ g/mol} \times 6 \times 10^{23}\ molecules/mol$$

$$= 2 \times 10^{10}\ molecules$$

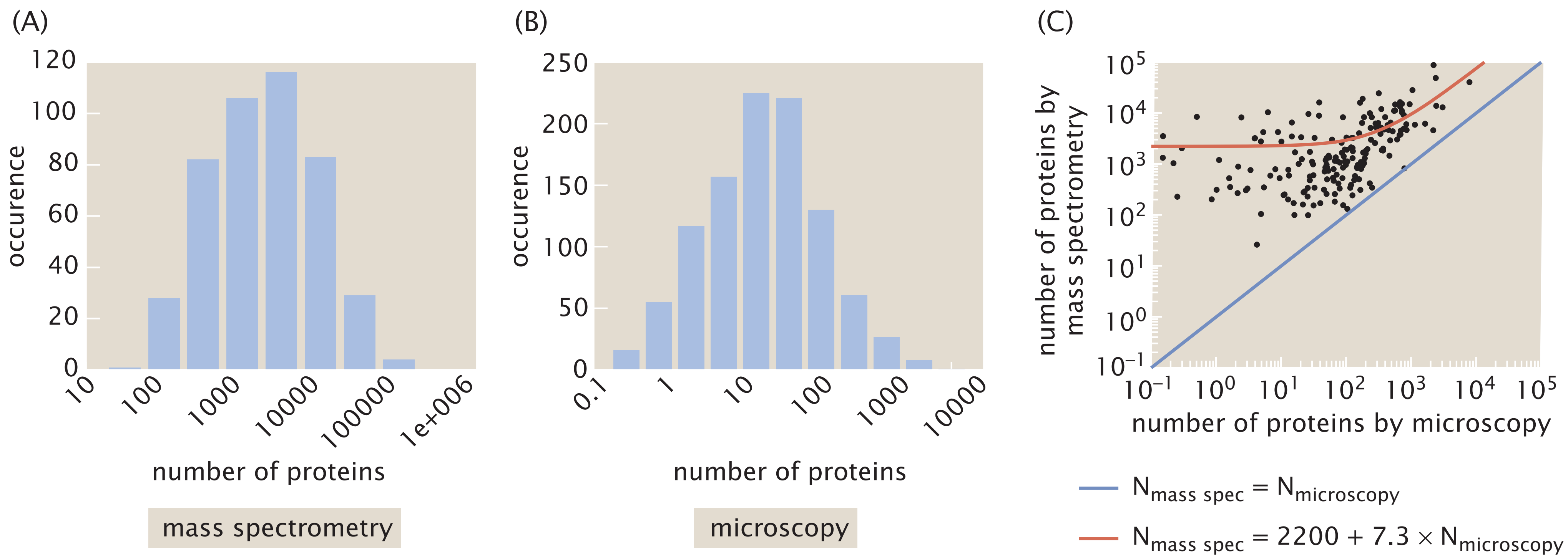
Simple methods often lead to very good measurements!

Table 2.1: Observed macromolecular census of an *E. coli* cell. (Data from F. C. Neidhardt et al., Physiology of the Bacterial Cell, Sinauer Associates, 1990 and M. Schaechter et al., Microbe, ASM Press, 2006.)

Substance	% of total dry weight	Number of molecules	
Macromolecules			
Protein	55.0	2.4×10^6	Our estimate ~ 3×10^6
RNA	20.4		
23S RNA	10.6	19,000	
16S RNA	5.5	19,000	
5S RNA	0.4	19,000	
Transfer RNA (4S)	2.9	200,000	
Messenger RNA	0.8	1,400	
Phospholipid	9.1	22×10^6	Our estimate ~ 20×10^6
Lipopolysaccharide (outer membrane)	3.4	1.2×10^6	
DNA	3.1	2	
Murein (cell wall)	2.5	1	
Glycogen (sugar storage)	2.5	4,360	
Total macromolecules	**96.1**		
Small molecules			
Metabolites, building blocks, etc.	2.9		
Inorganic ions	1.0		
Total small molecules	**3.9**		

Why should we care about these numbers?

- Quantitative understanding of the molecules involved and the physical space where they function — needed for building a realistic model
- Quantification of the effect of ‘molecular crowding’
- To design ‘realistic’ *in vitro* experiments
- To estimate the rates of synthesis of biomolecules during the cell cycle
- Quantification of cell-to-cell variability



- Understanding the ‘baseline’ for comparative biological experiments