

# Key Numbers for Cell Biologists

## Cell sizes:

1. Bacteria (*E. coli*):  $\approx 0.7\text{-}1.4\ \mu\text{m}$  diameter,  $\approx 2\text{-}4\ \mu\text{m}$  length,  $\approx 0.5\text{-}5\ \mu\text{m}^3$  in volume;  $10^8\text{-}10^9$  cell/ml for culture with  $\text{OD}_{600}\approx 1$
2. Yeast (*S. cerevisiae*):  $\approx 3\text{-}6\ \mu\text{m}$  diameter,  $\approx 20\text{-}160\ \mu\text{m}^3$  in volume
3. Mammalian cell volume:  $100\text{-}10000\ \mu\text{m}^3$ ; HeLa:  $500\text{-}5000\ \mu\text{m}^3$  (adherent on slide  $\approx 15\text{-}30\ \mu\text{m}$  diameter)

## Length Scales Inside Cells

4. Nucleus volume  $\approx 10\%$  of cell volume
5. Cell membrane thickness  $\approx 4\text{-}10\ \text{nm}$
6. "Average" protein diameter  $\approx 3\text{-}6\ \text{nm}$
7. Base pair:  $2\ \text{nm}$  (D) x  $0.34\ \text{nm}$  (H)
8. Water molecule diameter  $\approx 0.3\ \text{nm}$

## Division, Replication, Transcription, Translation & Degradation Rates

at  $37^\circ\text{C}$  with a temperature dependence  $Q_{10}$  of  $\approx 2\text{-}3$

9. Cell cycle time (exponential growth in rich media): *E. coli*  $\approx 20\text{-}40\ \text{min}$ ; yeast  $70\text{-}140\ \text{min}$ ; human cell line (HeLa):  $15\text{-}30\ \text{hours}$
10. Rate of replication by DNA polymerase *E. coli*  $\approx 200\text{-}1000\ \text{bases/s}$ ; human  $\approx 40\ \text{bases/s}$ . Transcription by RNA polymerase  $10\text{-}100\ \text{bases/s}$
11. Translation rate by ribosome  $10\text{-}20\ \text{aa/s}$
12. Degradation rates (proliferating cells): mRNA half life  $<$  cell cycle time; protein half life  $\approx$  cell cycle time

## Concentrations

13. Concentration of  $1\ \text{nM}$  in: *E. coli* is  $\approx 1\ \text{molecule/cell}$ ; HeLa  $\approx 1,000\ \text{molecules/cell}$
14. Characteristic concentration for a signaling protein  $\approx 10\ \text{nM}\text{-}1\ \mu\text{M}$
15. Water content:  $\approx 70\%$  by mass; General elemental composition (dry weight) of *E. coli*:  $\approx \text{C}_4\text{H}_7\text{O}_2\text{N}_1$ ; Yeast  $\approx \text{C}_6\text{H}_{10}\text{O}_3\text{N}_1$
16. Composition of *E. coli* (dry weight):  $\approx 55\%$  protein,  $20\%$  RNA,  $10\%$  lipids,  $15\%$  others
17. Protein conc.  $\approx 100\ \text{mg/ml} = 3\ \text{mM}$ .  $10^6\text{-}10^7$  per *E. coli* (depending on growth rate); Total metabolites (MW  $< 1\ \text{kD}$ )  $\approx 300\ \text{mM}$

## Energetics

18. Membrane potential  $\approx 70\text{-}200\ \text{mV}$   $\rightarrow$   $2\text{-}6\ k_B\text{T}$  per electron ( $k_B\text{T}$  = thermal energy)
19. Free energy ( $\Delta G$ ) of ATP hydrolysis under physiological conditions  $\approx 40\text{-}60\ \text{kJ/mole}$   $\rightarrow \approx 20k_B\text{T/molecule ATP}$ ; ATP molecules required to make an *E. coli* cell  $\approx 10\text{-}50 \times 10^9$
20.  $\Delta G^0$  resulting in order of magnitude ratio between products and reactants concentrations:  $\approx 6\ \text{kJ/mol} = \approx 60\ \text{meV} = \approx 2\ k_B\text{T}$

Click on a number to see full description and reference:  
[www.BioNumbers.org](http://www.BioNumbers.org)

## Diffusion and Catalysis Rate

21. Diffusion coefficient for an "average" protein: in cytoplasm  $D \approx 5\text{-}15\ \mu\text{m}^2/\text{s}$   $\rightarrow \approx 10\ \text{millisec}$  to traverse an *E. coli*  $\rightarrow \approx 10\ \text{s}$  to traverse a mammalian (HeLa) cell; small metabolite in water  $D \approx 500\ \mu\text{m}^2/\text{s}$
22. Diffusion limited on-rate for characteristic protein  $\approx 10^8\text{-}10^9\ \text{s}^{-1}\text{M}^{-1}$   $\rightarrow$  for a protein substrate of concentration  $\approx 1\ \mu\text{M}$  the diffusion limited on-rate is  $\approx 10\text{-}100\ \text{s}^{-1}$  thus limiting the catalytic rate  $k_{\text{cat}}$

## Genomes, Mutation & Error Rates

23. Genome size: *E. coli*  $\approx 4 \times 10^6\ \text{bp}$ ; *S. cerevisiae* (yeast)  $\approx 12 \times 10^6\ \text{bp}$ ; *C. elegans* (nematode)  $\approx 100 \times 10^6\ \text{bp}$ ; *D. melanogaster* (fruit fly)  $\approx 120 \times 10^6\ \text{bp}$ ; *A. thaliana* (arabidopsis)  $\approx 160 \times 10^6\ \text{bp}$ ; *M. musculus* (mouse)  $\approx 3,000 \times 10^6\ \text{bp}$ ; *H. sapiens* (human)  $\approx 3,000 \times 10^6\ \text{bp}$ ; *T. aestivum* (wheat)  $\approx 17,000 \times 10^6\ \text{bp}$
24. Mutation rate in DNA replication  $\approx 10^{-10}$  per bp
25. Misincorporation rate: transcription  $\approx 10^{-4}$  per nucleotide; translation  $\approx 10^{-3}\text{-}10^{-4}$  per amino-acid

Useful biological numbers extracted from the literature. Numbers and ranges should only serve as "rule of thumb" values. References are in the online annotated version at the BioNumbers website. Consult website and original references to learn about the details of the system under study including growth conditions, method of measurement, etc.