

## Useful fundamental numbers in molecular biology



The numbers quoted here were extracted from the literature. They should only serve as “rule of thumb” values. Consult the full references to learn about the specific system under study, growth conditions, measurement method etc. Full references at: [www.bioNumbers.org](http://www.bioNumbers.org)

### **Cell sizes:**

Bacteria (e.coli):  $\sim 1\mu\text{m}$  diameter,  $2\mu\text{m}$  length,  $\sim 1\mu\text{m}^3$  in volume;  $10^9$  cells/ml in an overnight culture (OD600 $\sim$ 1)

Yeast (Saccharomyces cerevisiae):  $\sim 5\mu\text{m}$  diameter,  $\sim 50\mu\text{m}^3$  in volume

Mammalian (HELA) cell -  $\sim 2,000\mu\text{m}^3$  in volume, adherent cell on a slide  $\sim 20\mu\text{m}$  diameter  $\rightarrow$   $\sim 100,000$  cells in a confluent well of a 96 multiwell plate

### **Organelles and cell constituents:**

Mammalian cell nucleus  $\sim 10$  micron diameter

Mitochondria  $\sim 1$ - $2$  micron length,  $\sim 0.2$ - $0.7$  micron diameter

Chloroplast  $\sim 4$  micron length,  $\sim 1$  micron diameter

Cell membrane  $\sim 5$ - $10$  nm, “average” protein  $\sim 2$ nm, water molecule  $\sim 0.2$ nm

### **Concentrations**

Absolute numbers “rule of thumb”: concentration of 1 nM in a cell the volume of e.coli is  $\sim 1$  molecule/cell  $\rightarrow$

$1\mu\text{M}$   $\sim 1000$  molecules/bacterial (e.coli) cell;  $2,000,000$  molecules/mammalian (HELA) cell.

Characteristic concentration for a signaling protein  $\sim 10$  nM- $1\mu\text{M}$

Water content:  $\sim 50$ - $70\%$  of cell. General elemental composition dry mass: C:H<sub>1.77</sub>:O<sub>0.49</sub>:N<sub>0.24</sub>

Composition of dry weight of an e.coli:  $\sim 55\%$  protein,  $20\%$  RNA,  $10\%$  Lipids,  $15\%$  others.

Number of proteins in an e.coli cell  $3$ - $10 \times 10^6$  (depending on growth rate)

### **Energetics**

$\Delta G$  needed to achieve an order of magnitude ratio of concentrations:  $\sim 6$  kJ/mole =  $\sim 2$  kT =  $\sim 60$  meV

Energetic contribution of a hydrogen bond:  $\sim 6$ - $24$  kJ/mole  $\rightarrow$  1-4 orders of magnitude concentration change

$\Delta G$  of ATP hydrolysis under physiological conditions  $\sim 50$  kJ/mole  $\rightarrow$   $\sim 20$  kT

### **Diffusion and catalysis rate**

Diffusion coefficient for a protein in the cytoplasm  $D \sim 5$ - $50\mu\text{m}^2/\text{sec}$   $\rightarrow$   $\sim 10$  millisecond to reach from one end of an e.coli to the other,  $\sim 10$  sec to traverse a mammalian (HELA) cell.  $D(\text{metabolite}) \sim 500\mu\text{m}^2/\text{sec}$ .

Diffusion limited on-rate for a characteristic protein  $\sim 10^8$ - $10^9$  1/sec/Molar  $\rightarrow$  for a protein substrate of concentration  $\sim 1\mu\text{M}$  the diffusion limited on rate is  $\sim 10$ - $100$  Hz thus giving a limit on the catalytic rate  $K_{\text{cat}}$

### **Replication, transcription, translation rates**

Rate of DNA replication by DNA polymerase  $\sim 1000$  bp/sec  $\rightarrow$   $\sim 60$  minutes to replicate whole e.coli genome.

To achieve faster growth rates requires simultaneous internal replication forks.

Rate of transcription by RNA polymerase  $\sim 80$  bp/sec

Rate of translation by the ribosome  $\sim 20$  aa/sec

### **Mutation and error rates**

Mutation rate in DNA replication  $\sim 10^{-9}$  per bp in e.coli

Error rate in translation  $\sim 10^{-4}$  per amino-acid

Please send corrections and ideas for more bioNumbers to [bioNumbers@gmail.com](mailto:bioNumbers@gmail.com)

# B10NUMB3R5

THE DATABASE OF USEFUL BIOLOGICAL NUMBERS

ATP to make one cell: ~55 billion  
 Volume occupied by RNA: 6%  
 Number of tRNA/cell: ~200,000  
 Speed: 50  $\mu\text{m}/\text{sec}$   
 Ribosomes: 6,800 - 72,000  
 Proteins: ~ $3.6 \times 10^6$   
 Translation rate: 12 - 21 aa/sec  
 Volume occupied by water: 70%



Generation time: 4 days  
 Cells in an adult male: 1031  
 Number of genes: 20,621  
 Eggs laid during lifetime: 300  
 Size of Genome: 100Mbp  
 Life span: 2-3 weeks  
 Run speed at 20°C: 0.13mm/sec  
 Cells in hatched larvae: 556



Median haploid volume: 42  $\mu\text{m}^3$   
 Number of ribosomes: ~200,000  
 Nucleus volume: 7% of cell  
 mRNA out of total RNA: 5%  
 mRNA in cell: 15,000  
 Kcat of Pyruvate kinase: 71,400/min  
 Cell diameter: ~5 $\mu\text{m}$   
 RNA to DNA ratio: 50



Total number of taste buds: 10,000  
 Cell divisions in a life-time:  $10^{17}$   
 Abundance of p53 per cell: ~160,000  
 Average brain weight: ~1350g  
 Hairs on the head: 90,000-150,000  
 Diameter of erythrocytes: 7.5 $\mu\text{m}$   
 Weight of skin: 4.1 Kg  
 Average time between blinks: 2.8 Sec

See a collection of useful fundamental numbers in molecular biology on other side of page

BioNumbers ([bioNumbers.org](http://bioNumbers.org)) is the database of useful biological numbers. It aims to enable you to find in one minute any common biological number important for your research, such as the rate of translation of the ribosome, concentrations of metabolites or the number of bacteria in your gut. You will find full references, comments and related numbers that are useful. Check it out at: [www.bioNumbers.hms.harvard.edu](http://www.bioNumbers.hms.harvard.edu).

Please send suggestions and comments: [ron\\_milo@hms.harvard.edu](mailto:ron_milo@hms.harvard.edu)

The screenshot shows the BioNumbers website interface. At the top, there's a navigation menu with links like 'home', 'search', 'browse', 'download', 'resources', 'about us', 'quick submit', and 'login to submit'. The main content area features a search bar with the text 'Find Terms:' and a dropdown menu for 'Organism: (all)'. Below the search bar, there's a table titled 'Below are 10 random bioNumbers. Click a row for more details'.

ID	Project	Organism	Value	Units	Units
120075	The number of kinases in the <i>C. elegans</i> genome	Nematode <i>Caenorhabditis elegans</i>	438		unitless
120043	Typical protein energy stores in a 150 lb man	Human <i>Homo sapiens</i>	25000		kcal
120067	Amount of water that cycles each year from the land to the atmosphere	Biosphere	~100		trillion barrels
120072	typical ratio of Oxygen to superoxide	Unspecified	1E-05		unitless
121564	Life span of worms	Unspecified	330		5-3 hours
121244	Concentration of UTP	<i>Arceuthobium discoloratum</i>	330		uM
121371	Fertilizer absorbed by Brazilian sugar cane as a percentage of total used	fruit apple able	30		percent
120140	velocity of chemical reaction and rate	<i>Escherichia coli</i>	1.4		min
121463	diameter of nematode caecum	African clawed frog <i>Xenopus laevis</i>	1.2-1.3		mm
120395	Ribosomes	African clawed frog <i>Xenopus laevis</i>	1e+12		ribosomes

Below the table, there's a text box with the following text: 'BioNumbers aims to enable you to find in one minute any common biological number that can be important for your research. BioNumbers is a collaborative community effort to establish a database of useful biological numbers. Search for a value you need for your research or out of curiosity. Use the tab click Submit to request numbers you need to know and credit not find - we will find them for you. The BioNumbers database contains 1674 numbers, and it's growing every day. More details and future directions can be found at <http://bioNumbers.org/wiki/BioNumbers>. We welcome all suggestions and comments for improving BioNumbers. Please send to [ron\\_milo@hms.harvard.edu](mailto:ron_milo@hms.harvard.edu)'.