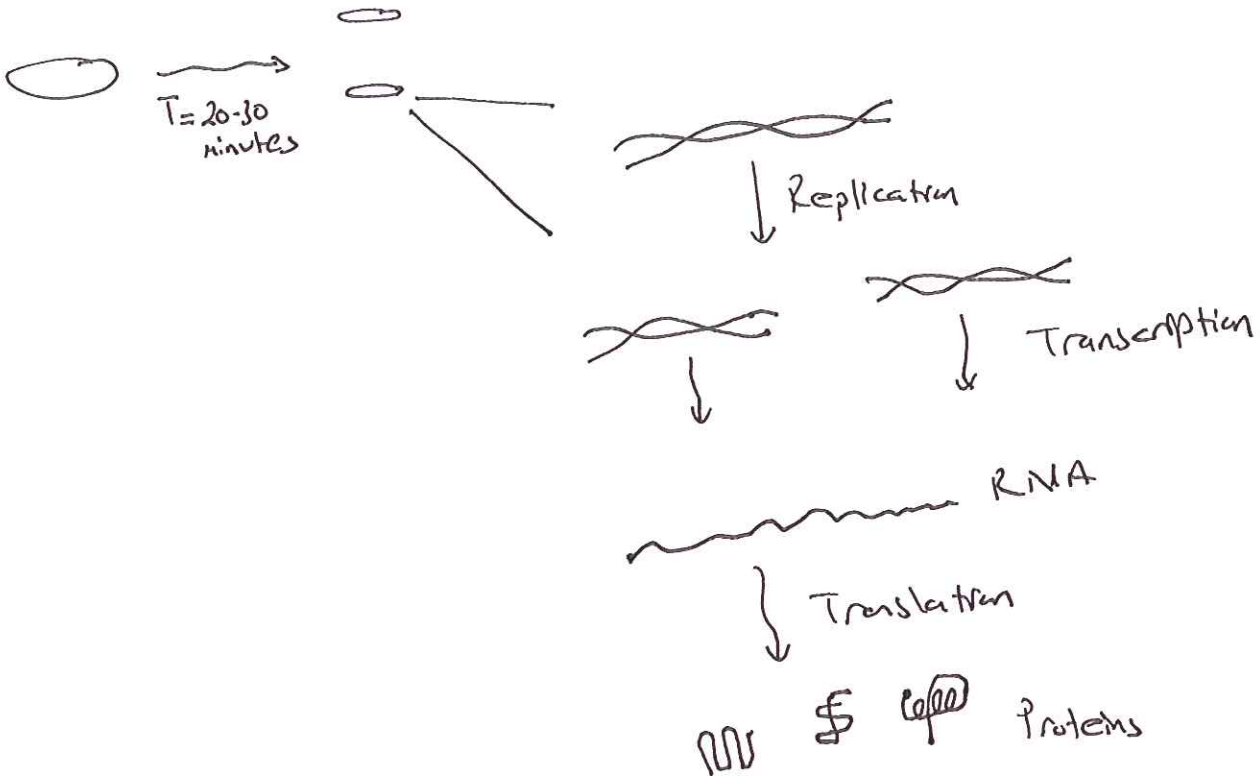
Timing in Cells

A division of single E. coli takes $T \simeq 20\text{-}30$ minutes.



Rate of DNA replication

$$\frac{\text{Number of base pairs}}{\text{time}} = \frac{\Delta N}{\Delta t} = \frac{5\times10^6}{30\text{min}} \simeq 1.6\times10^5/\text{min} = 2.6\times10^3 \text{ bp/s}$$

$$\frac{2.6\times10^3}{2} = 1.3\times10^3$$

↳ 2 polymerase operate on the genome.

Proteins: $\frac{4\times10^6 \text{ protein}}{1600 \text{ sec}} \simeq 2\times10^3$ protein/sec

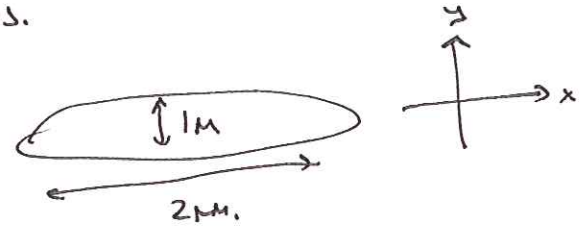
Diffusion time depends on the time scale.

$$t_{Diffusion} = \frac{x^2}{q \cdot D}$$

D: diffusion constant
x: length
q: Dimension factor

1D	$q = 2$
2D	$q = 4$
3D	$q = 6$

$$t_{e.coli} = \frac{C^2_{E.coli}}{q \cdot D} = \frac{1\,\mu m^2}{2 \times 100\,\mu m^2/s} = 0.005\,s = 5\,ms.$$



$$D_{protein} = 100\,\mu m^2/s$$

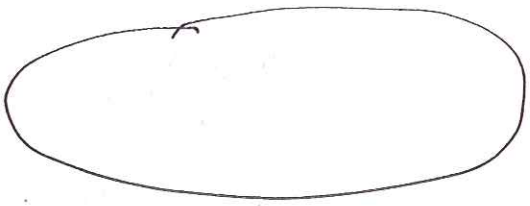
$$= \frac{4\,\mu m^2}{2 \times 100\,\mu m^2/s} = 0.020\,s = 20\,ms.$$

$$D = \frac{k_B T}{\gamma} = \frac{4 \times 10^{-21}\,Nm}{6 \times 3 \times 10^{-3}\,\frac{Ns}{m^2} \times 25 \times 10^{-9}\,m} = 10^{-10}\,m^2/s = 100\,\mu m^2/s$$

← Thermal energy

$$\gamma = 6\pi\eta R$$

η = Viscosity of the medium.
R = Radius of the protein



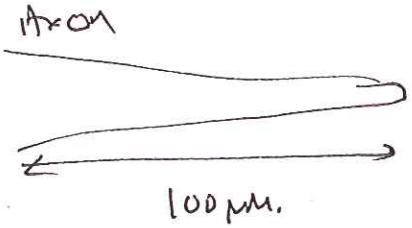
30μm

$$t = \frac{L^2_{cell}}{9.D} = \frac{900\mu m^2}{2 \times 100 \mu m^2/s} = 4.5\,s$$

$t_{cell} = 4.5$ sec.

(very slow process.!)

- Passive trasport is slow for Eukaryotic cells.
- E. Cells needs an active trasport system.
- Example; kinesin moving along the microtubules for trasport patems, organels etc.



$$t = \frac{L^2_{Axon}}{9.D} = \frac{10^4 \mu m^2}{2 \times 100 \mu m^2/s} = 50\,s.$$

A sngle signal takes 50s, it not efficient with passive trasport such as division.