Diffusion and Bacteria:

A Study in Biophysics

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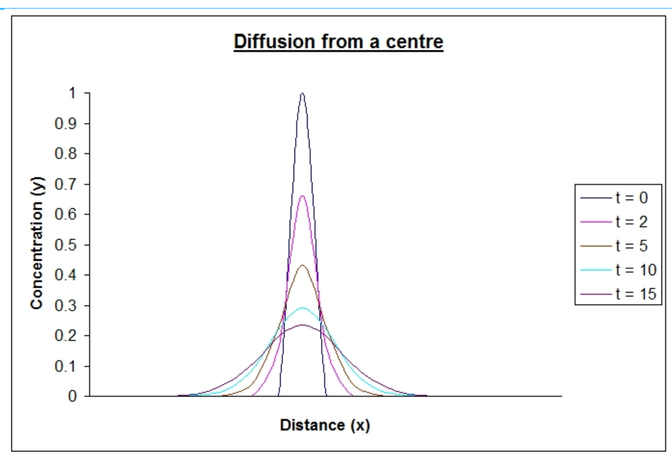
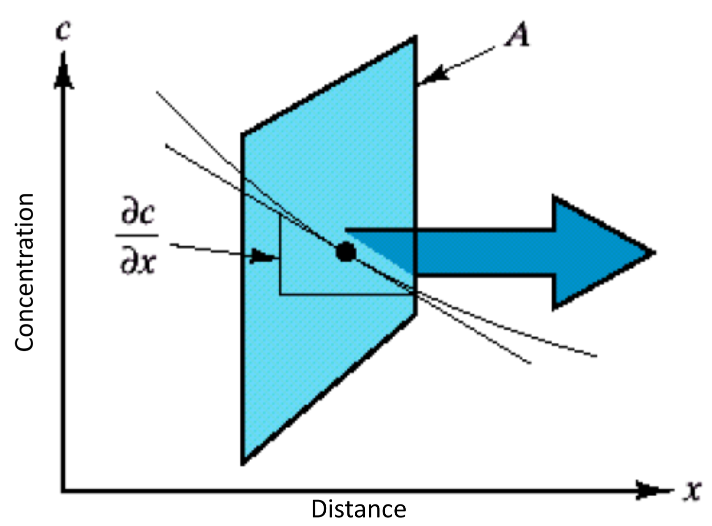
Diffusion

- Statistical probability of particles moving from high concentration to low concentration



Fick's Law

- Relationship between Flux (*j*) and Slope of Concentration Gradient (*dc/dx*)



$$j = -D\frac{dc}{dx}$$

Diffusion Coefficients

- Physical property of a binary system
- Rate of area per time (dimensionally)
- Similar to Friction Coefficients
- Ranges for different binary systems
  - Gas – Gas = 10^{-5} m^2/s
  - Gas – Liquid = 10^{-9} m^2/s
  - Gas – Solid = 10^{-13} m^2/s
- Dimensionally
  - *D = Lv*

Bacteria

- Utilize *Passive Transport* (Diffusion) to satisfy life functions
  - This places an upper limit on the size bacteria can be
  - Too big = Diffusion too slow to keep alive

Maximum Size of Bacteria

- Equate *Intake Rate* (I) to *Metabolic Rate* (M)
  - I – the rate at which O_2 can be taken into the bacterium through outer shell
  - M – the rate at which the bacterium can metabolize the O_2 through whole volume

$$I = Flux\ (j(r)) \times Surface\ Area\ of\ Sphere\ (4\pi r^2)$$

$$M = Experimental\ Consumption\ Rate\ (\alpha) \times Volume\ of\ Sphere\ (\tfrac{4}{3}\pi r^3)$$

- Solve for Radius

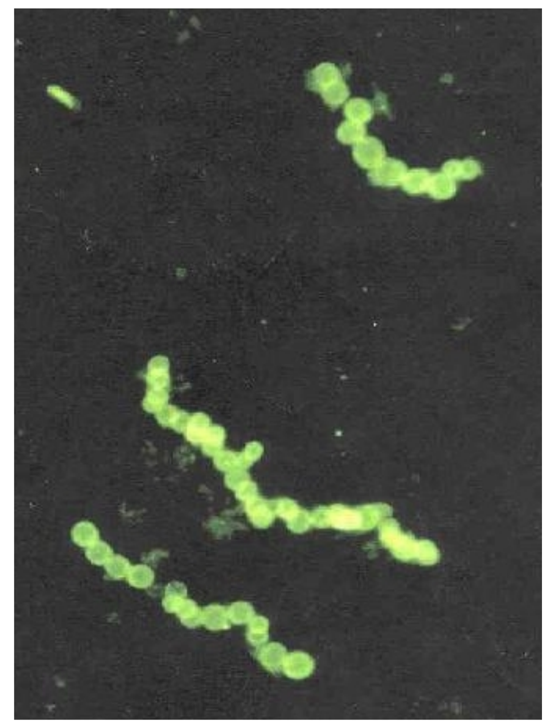
$$R = \sqrt{\frac{C_0(3)D}{\alpha}}$$

- Here there is only have dependence on constants or experimentally determined values

- Plugging in values I get

$$R = \sqrt{\frac{(.706\frac{mol}{m3})\,3\,(2.5\times10^{-9}\frac{m2}{s})}{1.1\frac{mol}{m3s}}} = 69.3\mu m$$

Thiomargarita Namibiensis



- Largest bacteria ever found
- Radius range: 50-150μm
- My calculation fits into this range
- Experimental values not "idealized" so my number on smaller end

Conclusion

- Diffusion is random molecular motion that follows a statistical probability
- Fick's Law, using concentrations and diffusion coefficients, in combination with known consumption rates, allows us to calculate upper size limit of bacteria
- This requires no biochemistry, only the physics of diffusion!

Works Cited

Levin, P. A., & Angert, E. R. (2015). Small but mighty: Cell size and bacteria. *Cold Spring Harbor Perspectives in Biology, 7*(7), a019216. doi:10.1101/cshperspect.a019216

Marshall, W. F., Young, K. D., Swaffer, M., Wood, E., Nurse, P., Kimura, A., . . . Roeder, A. H. K. (2012). What determines cell size? *BMC Biology, 10*(1), 101. doi:10.1186/1741-7007-10-101

Maximum dissolved oxygen concentration saturation table. Retrieved from https://dnr.mo.gov/env/esp/wqm/DOSaturationTable.htm

Nelson, P. (2014). *Biological physics* (5. print. ed.). New York, NY: Freeman.

Nuclear Waste.*20.3: Applications of diffusion*

Philip Nelson. (2003). *Biological physics: Energy, information, life* (5th ed.)

Russel, W. B. (1981). Brownian motion of small particles suspended in liquids. *Annual Review of Fluid Mechanics, 13*(1), 425-455. doi:10.1146/annurev.fl.13.010181.002233