$$N_T = N_0 \bullet 2^{(T/g)}$$

as time increases, t/g = 1, 2, 3 ..., thus 2^1, 2^2, 2^3, etc.

g is the generation time

N_0 is the number of cells at time T = 0

N_T is the number of cells at time T

$$\frac{dM}{dt} = \mu M$$ μ is the specific growth rate and M the mass

$$\frac{dM}{dt} = \mu M - \mu \frac{M^2}{G}$$ G is the maximal attainable population

A cube has a surface area of $6 \bullet x^2$. Its volume is x^3.
For a sphere, the surface area is $4 \bullet \pi \bullet r^2$, and the volume is $\pi \bullet r^3$.
For a cylinder, the surface area is $2 \bullet \pi \bullet r \bullet h$ (plus $2\pi r^2$ for the top and bottom of the cylinder), the volume is $\pi \bullet r^2 \bullet h$.
For a rectangle, the surface area is 2(d•w) + 2(l•d) + 2(l•w), the volume is d•w•l.

Heat conduction rates are defined by the relation:

$$P_{cond} = Q / t = k \bullet A \bullet [(T_a - T_b) / L]$$

where P_{cond} is the rate of conduction (transferred heat, Q, divided by time, t); k is the thermal conductivity; T_a and T_b are the temperatures of the two heat reservoirs a and b; A is the area; and L is the distance. Thermal conductivities of water and air are about 0.6 and 0024 W m^{-1} K^{-1}, respectively.

Thermal radiation is defined by the relation:

$$P_{rad} = \sigma \bullet \varepsilon \bullet A \bullet T^4$$

where P_{rad} is the rate of radiation; σ is the Stefan-Boltzmann constant ($5.6703 \bullet 10^{-8}$ W m^{-2} K^{-4}; ε is the emissivity (varies from 0 to 1 for a blackbody radiator); A is the area; and T is the temperature (in Kelvins). The *net* radiative emission or absorption will depend upon the difference in temperature:

$$P_{net} = \sigma \bullet \varepsilon \bullet A \bullet (T^4_{body} - T^4_{ambient})$$

$w \propto m \bullet h$ w is the work, m is the mass, and h is the height

$w \propto V_{muscle}$ V_{muscle} is the muscle volume

$$F = m \bullet a,\ F = m\frac{\Delta v}{t},\ F \bullet t = m \bullet \Delta v,\ w = F \bullet d$$

$\int r \bullet dm$ and $\int r^2 \bullet dm$ first and second moments of mass

$\int y \bullet dA$ and $\int y^2 \bullet dA$ first and second moments of area

$$\text{compression} = \rho \bullet h$$

$$h_{critical} = \frac{\text{compression}}{\rho}$$

$$F_{cr} = \frac{E \bullet I \bullet \pi^2}{L_{eff}^2}$$

$$I_x = \frac{\pi \bullet r^4}{4}$$

$$h = 0.851 \bullet \left[\frac{E}{\rho}\right]^{1/3} \bullet r^{2/3}$$

common name	species	diameter meters	height meters	Modulus of Rupture $GN \cdot m^{-2}$	Modulus of Elasticity $GN \cdot M^{-2}$	density $kg\ m^{-3}$	compression parallel to grain $MN \cdot m^{-2}$
Redwood	Sequoia sempervirens	7.6808	97.8408	0.074	9.40	436	42.4
Eastern Hemlock	Tsuga canadensis	1.6332	50.2920	0.059	8.30	431	21.2
Trembling Aspen	Populus tremuloides	0.9702	41.4528	0.059	8.22	401	14.8
White Pine	Pinus strobus	2.4174	40.2336	0.061	8.81	373	16.8
Sugar Maple	Acer saccharum	1.8030	35.0520	0.108	12.65	676	27.7
Yellow Poplar	Liriodendron tulipfera	3.0238	33.8328	0.064	10.38	427	18.3
Yellow Birch	Betula lutea	1.5038	31.6992	0.117	14.53	668	23.3
Black Locust	Robina pseudoacacia	2.5225	28.6512	0.134	14.20	798	70.2
Eastern Cottonwood	Populus deltoides	3.5898	28.3464	0.060	9.53	433	15.7
Hornbeam	Ostrya virginiana	0.9298	21.3360	0.100	11.76	762	n/a
Common Apple	Malus sylvestris	1.1400	21.3360	0.088	8.77	745	n/a
Dogwood	Cornus florida	0.8894	10.0584	0.105	10.64	796	n/a
			means	0.086	10.599	578.8	27.822

$$\Psi_{wv} = \frac{RT}{\overline{V}_w}\ln\left(\frac{\%\text{ relative humidity}}{100}\right) + \rho_w g h$$

where R is the gas constant (8.314 m^3 Pa mol^{-1} $^oK^{-1}$), T is the temperature (^{o}K), V_w is the partial molal volume of water ($1.805 \bullet 10^{-5}$ m^3 mol^{-1} at 20ºC [293ºK]). At 20ºC, the term RT/V_w is 135 MPa. The second term is the gravitational potential: ρ_w is the density of water (998.2 kg m^{-3} at 20ºC), g is the gravitational constant (9.807 m sec^{-2}) and h is the height.

The basic equation describing the flow velocity of a liquid through a tube is the Poiseuille equation[1]:

velocity (meters sec^{-1})

pressure difference (Pascal = 1 kg m^{-1} sec^{-1})

Tube radius

$$v = \left(\frac{\Delta p}{l}\right)\left(\frac{1}{4 \bullet \eta}\right)(R^2 - r^2)$$

Distance from center of tube

distance (meters)

viscosity (water = 0.01 gm cm^{-1} sec^{-1}, or Pa sec)

The fastest velocity is at the center of the tube (r = 0):

$$v = \left(\frac{\Delta p}{l}\right)\left(\frac{1}{4 \bullet \eta}\right) R^2$$

$$J_v = \left(\frac{\Delta p}{1}\right)\left(\frac{\pi}{8 \bullet \eta}\right) \bullet R^4$$

density (water = 1 gm cm^{-3})

velocity (cm sec^{-1})

tube diameter (cm)

$$R_e = \frac{\rho \bullet \nu \bullet l}{\eta}$$

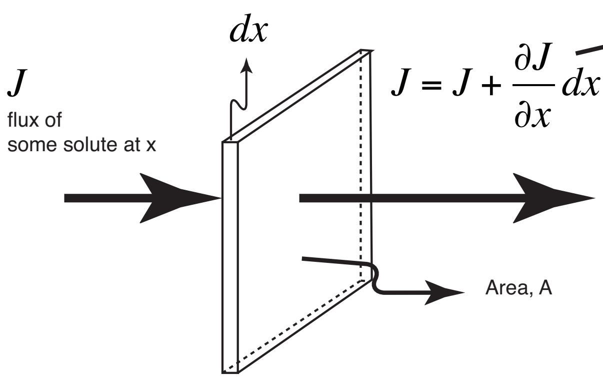
viscosity (water = 0.01 gm cm^{-1} sec^{-1})

flux, J (mol cm^{-2} sec^{-1})

concentration gradient, dc/dx with units of (mol cm^{-3})/(cm), or mol cm^{-4}.

$$J = -D \bullet \frac{dc}{dx} \Rightarrow \left(\frac{cm^2}{sec}\right)\left(\frac{mol}{cm^4}\right) \Rightarrow \left(\frac{mol}{sec \bullet cm^2}\right)$$

Diffusion coefficient with units of cm^2 sec^{-1}



$$J = J + \frac{\partial J}{\partial x} dx$$

The change in flux over the small distance dx

$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial x^2}$$

$$D = \frac{RT}{N} \bullet \frac{1}{6 \bullet \pi \bullet \eta \bullet r}$$

$$< x^2(t) >= 2Dt$$

$$r = \sqrt{6 \bullet D \bullet t}$$

$$J = D \frac{K_p}{d} [c_{outside} - c_{inside}]$$

where $D \frac{K_p}{d} = P$, the permeability coefficient with

units of $\frac{\frac{cm^2}{sec}}{cm}$, or cm•$sec^{-1}$

$$\frac{F_{inertial}}{F_{frictional}} = \frac{l^3 \bullet \rho \bullet \nu^2 / r}{\eta \bullet l^3 \bullet \left(\nu / r^2 \right)} = \frac{\rho \bullet \nu \bullet r}{\eta} = R_e$$

The drag (D) on an object is defined by:

fluid density

velocity

$$D = \frac{1}{2} \bullet \rho \bullet V^2 \bullet A \bullet C_D$$

frontal area

drag coefficient (shape-dependent)

$$m\left(-\frac{d\upsilon}{dt} \right) = 6 \bullet \pi \bullet \eta \bullet \mathrm{r} \bullet \upsilon$$

$$\upsilon(\mathrm{t}) = \upsilon_0 e^{\left(-\frac{6 \bullet \pi \bullet \eta \bullet r}{m} \bullet t \right)}$$

$$p_0(t) = e^{(-\lambda t)}$$

$$p(k,\mu) = \frac{\mu^k}{k!} e^{-\mu}$$

$$\mathrm{Rotor}_{(n)} + \mathrm{m}H^+_{\mathrm{outside}} \longleftrightarrow \mathrm{Rotor}_{(n+1)} + \mathrm{m}H^+_{\mathrm{inside}}$$

$$\mathrm{ADP} + \mathrm{P_i} + \mathrm{mH}^+_{\mathrm{outside}} \longleftrightarrow \mathrm{ATP} + \mathrm{mH}^+_{\mathrm{inside}}$$

gas constant

Faraday constant

Voltage

$$\mu = \mu^{\circ} + \mathrm{RT} \ln(a_{H^+}) + zF\Psi$$

temperature

activity of protons

$$\Delta \mathrm{G}_{\mathrm{ATP}} = \Delta \mathrm{G}^{\circ}_{\mathrm{ATP}} + \mathrm{RT} \ln\left(\frac{[ATP]}{[ADP][P_i]} \right)$$

$$\Delta G_{\text{total}} = n \bullet \Delta\mu_{H^+} + \Delta G_{ATP} = 0$$

$$n \bullet \left(RT \ln\left(\frac{a_{H^+}^{inside}}{a_{H^+}^{outside}}\right) + F\Delta\Psi\right) + \Delta G^{o}_{ATP} + RT \ln\left(\frac{[ATP]}{[ADP][P_i]}\right) = 0$$

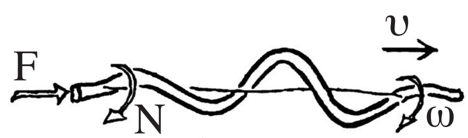
$$\Delta\mu_{H^+} = \frac{RT}{F} \ln\left(\frac{a_{H^+}^{inside}}{a_{H^+}^{outside}}\right) + \Delta\Psi \quad \text{(units: mV)}$$

RT/F is about 25 mV at 20ºC.

Both velocity and rotation contribute to both the force and torque.

$$F = A\upsilon + B\omega$$

$$N = C\upsilon + D\omega$$



$$\mathbf{P} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

The constants A, B, C and D (proportional to the viscosity and the size and shape of the ‘propellor’) comprise the propulsion matrix **P**.