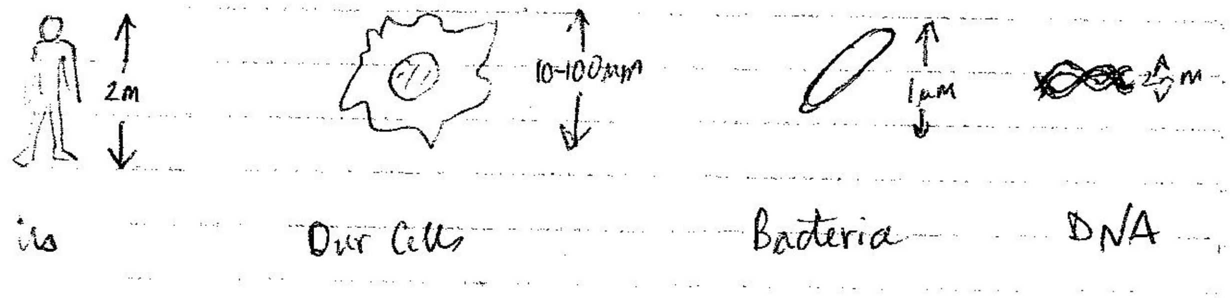
21st Jan, 2014

Lecture 1

Length scales



← Dominated by Thermal Fluctuations →

Objects like cells/molecules interact strongly with their environment, the fluid they are immersed in.

Result: Dissipation / Drag

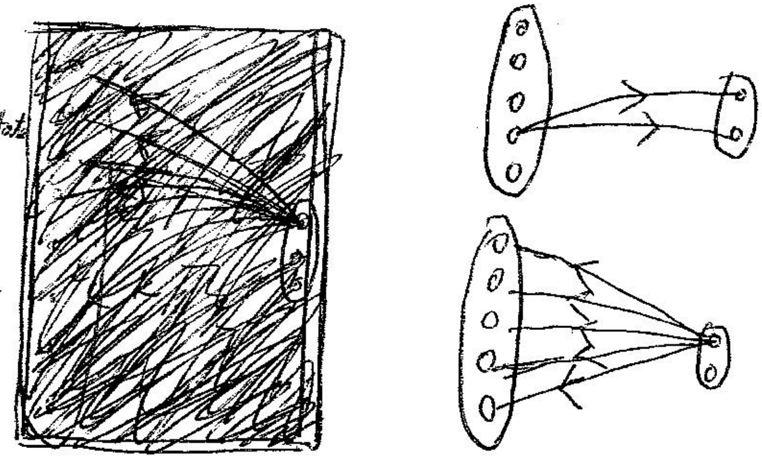
Thermal Fluctuation / Brownian motion

The first process takes energy away and the second seem to donate back energy. These two processes are closely related.

The hallmark of thermal fluctuation dominated dissipative dynamics is apparent irreversibility.

'Irreversibility' arises out of microscopically reversible dynamics from describing the system interms of <u>macrostates</u> rather than <u>microstates</u>.

Even if each microstate to another microstate transition is equally likely, the 'size' of macrostates decide the macrostate transition rates



Irreversibility is associated with <u>entropies</u> of different macrostates.

For a macrostate with Ω equally likely microstates, entropy S goes as $\log \Omega$

Boltzmann $\quad S = k_B \ln \Omega$

<u>Excursion</u>: Shannon Entropy

$H = \log_2 \Omega$ $\quad$ # of bits necessary to specify a microstate

More generally $H = \sum_i p_i \log_2 \frac{1}{p_i}$

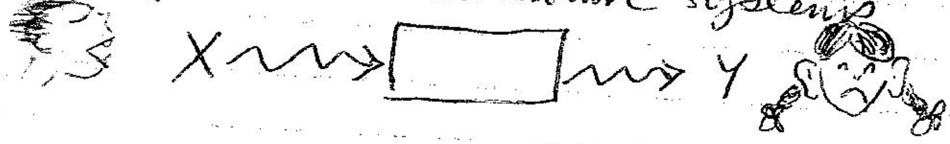
When $i = 1, \dots, \Omega$ and $p_i = \frac{1}{\Omega}$, we get $H = \log_2 \Omega$.

Shannon entropy is useful for defining <u>Mutual Information</u>.

$$I(X,Y) = H(X) + H(Y) - H(X,Y)$$

Entropy of joint distribution. Would be less than $H(X)+H(Y)$ if X and Y are not independent.

Useful in communication systems



End of Excursion

Entropy represents the degree of disorder. A precise way to think of the degree of disorder is to think of number bits need to specify a microstate in the macrostate. That is precise Shannon's Entropy. So

$$\text{Entropy} \longleftrightarrow \text{Disorder} \longleftrightarrow \text{Information}$$

(microscopic configurations)

Heat tranfer is transfer of energy to the microscopic degrees of freedom, which may be hard to extract back, or in some sense, less usable.

The natural scale for such molecular energy is $k_B T$ (more about it later).

$$k_B = \frac{R \leftarrow \text{Gas const}}{N_A \leftarrow \text{Avogadro number}}$$

$$k_B = 1.38 \times 10^{-23} \frac{J}{K} \qquad T_r \approx 300\,K$$

for close to room temp phenomena

$$\boxed{k_B T_r = 4.1 \times 10^{-21} J = 4.1 \text{ pN nm}}$$

1 nm ~ molecular length scales

1 pN ~ 'Thermal/Entropic' forces

'Puzzle' of Biological order!

Isolated system: Entropy increases

Open system! $A \rightleftarrows B \rightleftarrows C$

Energy flux allows lower 'entropy' states in absense of thermal equilibrium.

 $\longrightarrow$ activated molecules $\longrightarrow$ Dissipation in the bath.

(almost like population inversion)