TUTORIAL 2

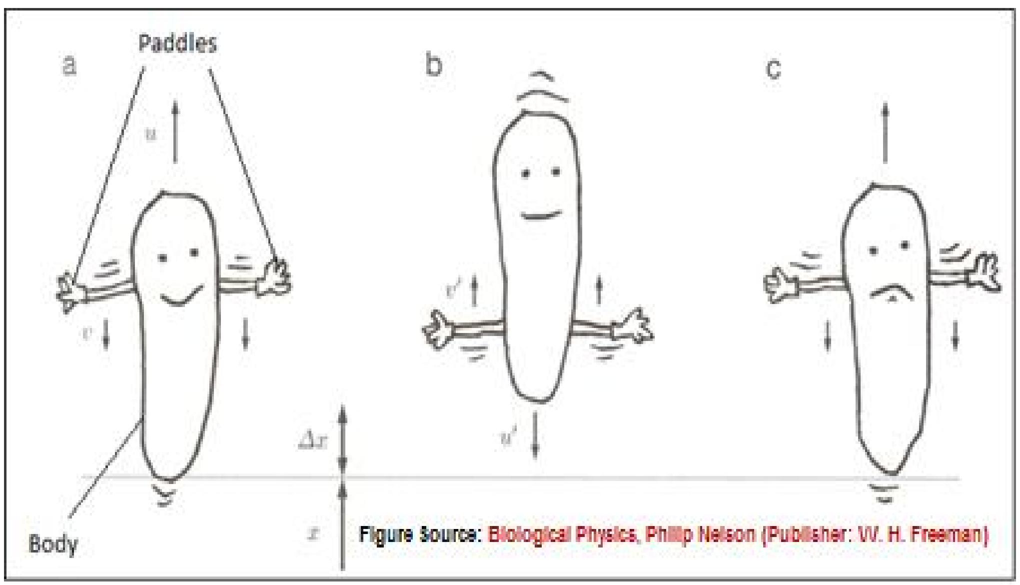
BB 101: MODULE II

PHYSICAL BIOLOGY

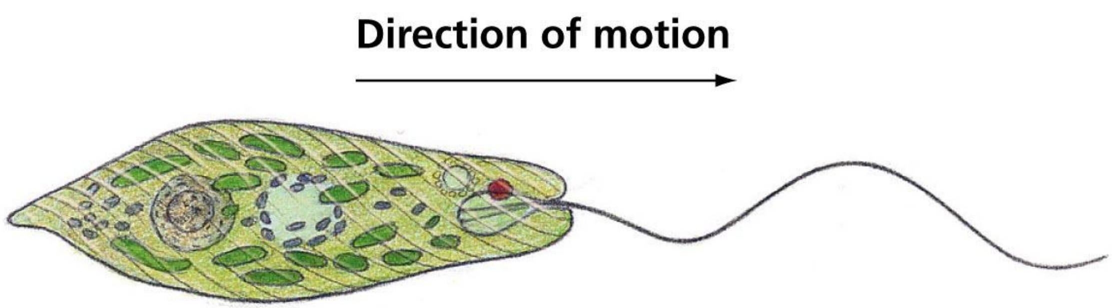
Reciprocal Motion in Newtonian Fluid

1. Consider a microscopic swimmer trying to make progress by cycling between the forward and backward strokes of its paddles as shown in Fig. A. (a) On the first stroke, the paddle move forward at relative speed v, propelling the body through the fluid at speed u. (b) On the second stroke, the paddle move forward at relative speed v', propelling the body backward at speed u' (c) Then the cycle repeats. Assume this is low Reynolds number motion where moving the body through the fluid requires a force determined by drag coefficient γ_1 and moving the paddles through the fluid requires a force determined by a different constant γ_2. Show that reciprocal motion like this cannot give net progress in low Reynolds number environment.

Figure A



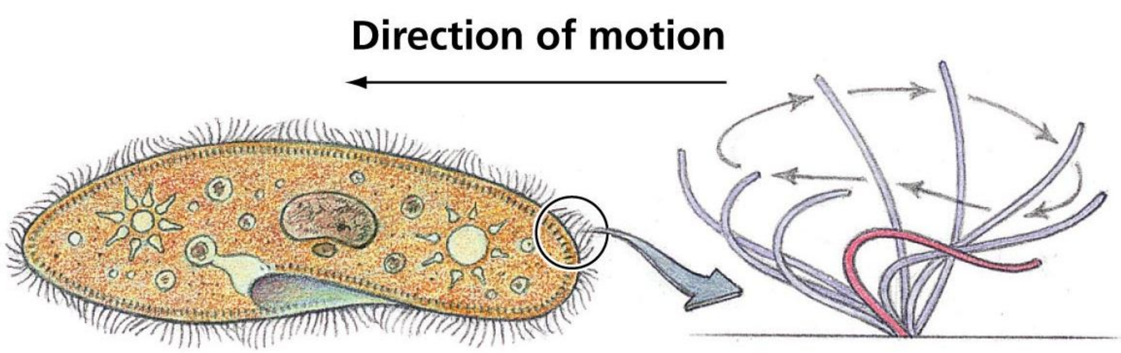
Motion of Cilia and Flagella



(a) Flagella

Watch rotory motor powered helical motion of bacterial flegellum on following link:

https://www.youtube.com/watch?v=a_5FToP_mMY



(b) Cilia

Watch cilium powered motion of paramecium on following link:

https://www.youtube.com/watch?v=WFpBRfLtbIo

Watch collective ciliary motion on following link:

https://www.youtube.com/watch?v=FQwqhblxz3I

2. Bacterial use flagella motor to rotate the helical flagellum to generate the propulsive force. Provide a qualitative explanation that if a thin, rigid helical rod as shown in Fig. B is cranked about its helix axis at a certain angular speed then it can generate a net force propulsive force.

Figure B

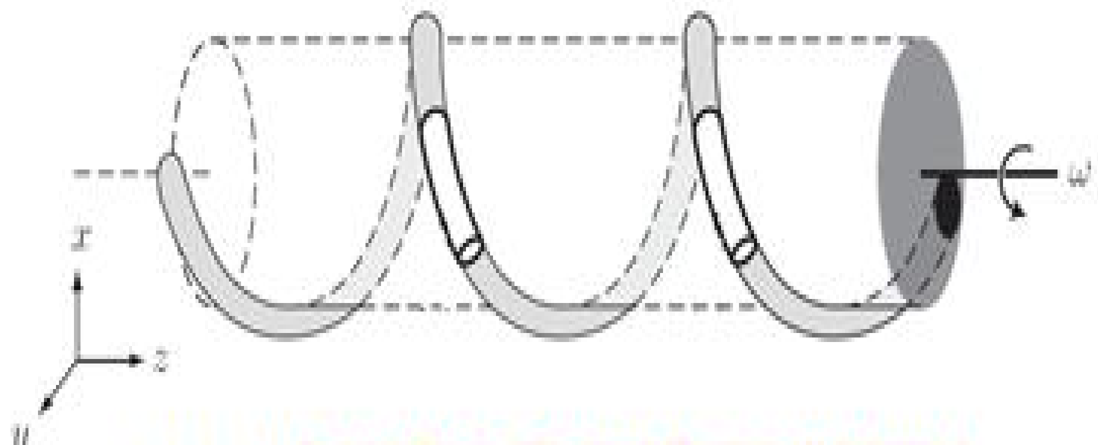


Figure Source: Biological Physics, Philip Nelson (Publisher: W. H. Freeman)

3. *E. coli* swims at about 20μm/s by rotating a bundle of helical flagella. If the motors were to turn 10 times faster than normal, what would their swimming speed be? If their fluid environment was made 10 times more viscous but the motors were to turn at same rate, what would the swimming speed be? How does the power output of the motor change in these two hypothetical situations?

Random walk leads to diffusive behavior

4. The aim of this problem is to show that a random walk leads to diffusive behavior. Suppose there is a drunkard person, as shown in Fig. C, walking along a line such that he takes steps of L, either to the left or right, with equal probability. So that his position x_N after taking N such random steps is given by $< (x_N)^2 >= NL^2$, where $< >$ denotes average.

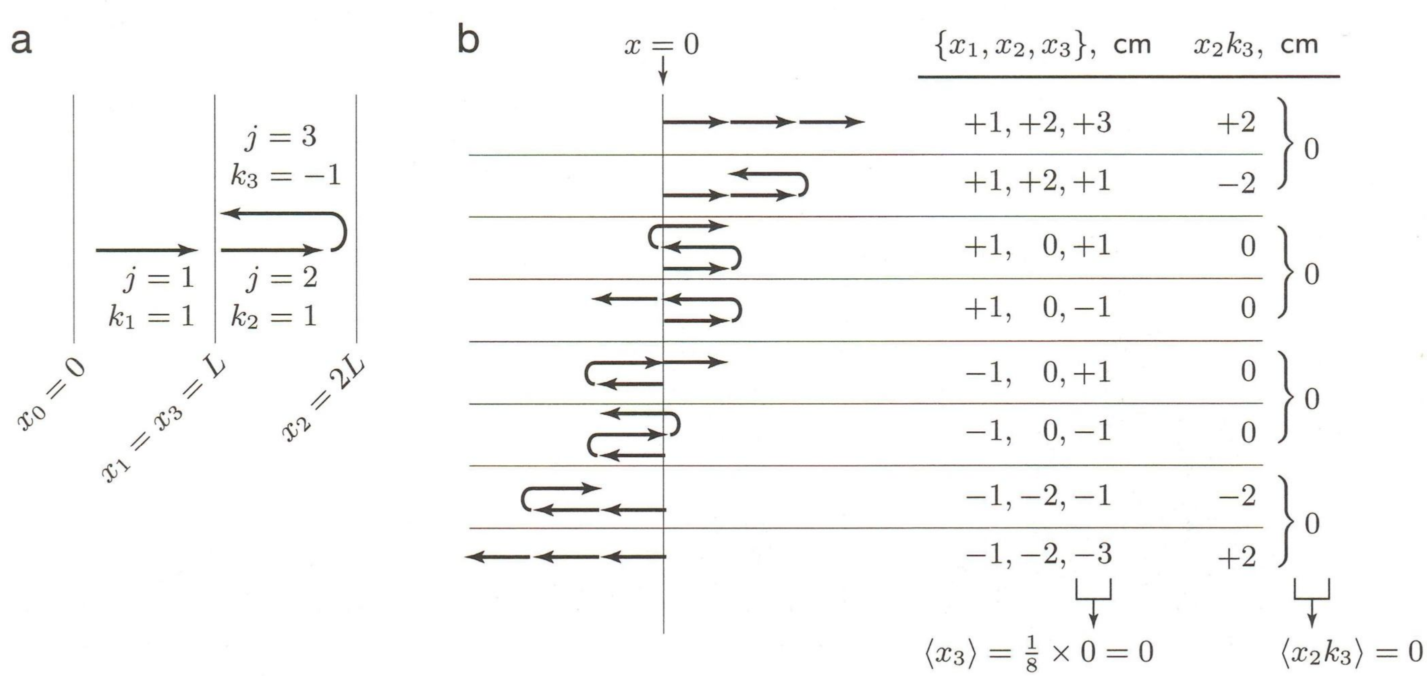


Figure Source: Biological Physics, Philip Nelson (Publisher: W. H. Freeman)

Application of Boltzmann Law

5. Consider a chain of four distinguishable beads with energy ϵ. This chain can switch between open conformation(s) or closed conformation(s) due to change of bond angles by 90^0 due to thermal fluctuations. Assume that energy of this system is not changed due to change of bond angles. However, if the distance two un-bonded beads due to change of bond angles become equal to bond length, then energy of the chain reduces by ϵ. Find out the partition function for this system. What will be the conformation of the chain at temperature T=0.