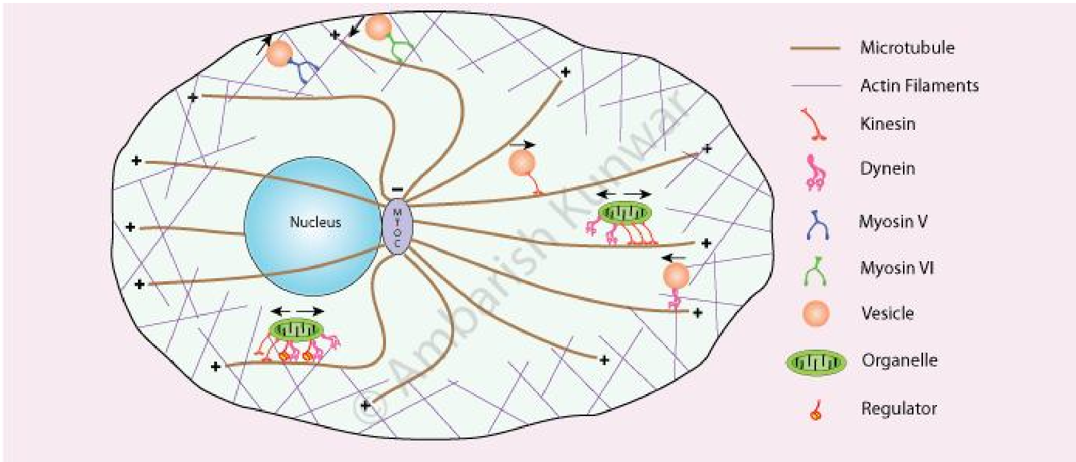
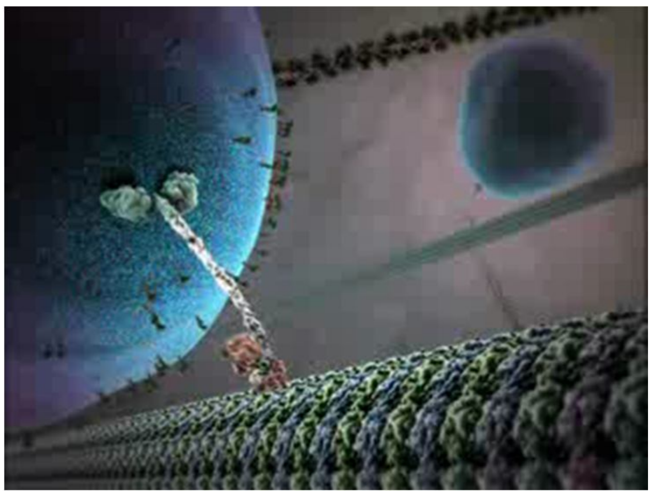
TUTORIAL 1

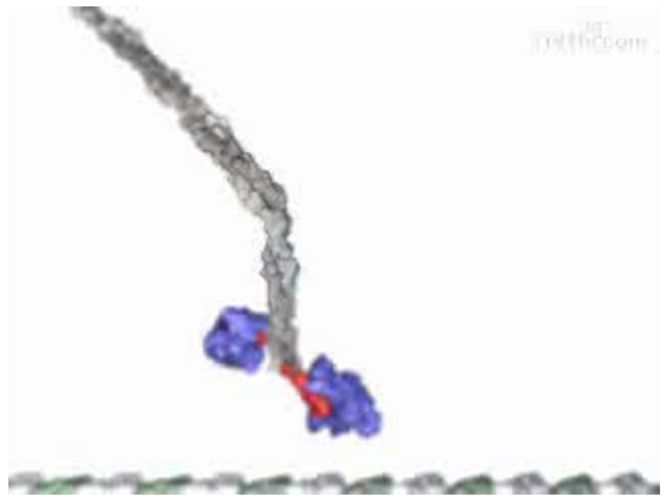
# BB 101: MODULE II

# *PHYSICAL BIOLOGY*

# Molecular Motors





Video Source: http://multimedia.mcb.harvard.edu/

Video Source: https://valelab.ucsf.edu/external/moviepages/moviesMolecMotors.html

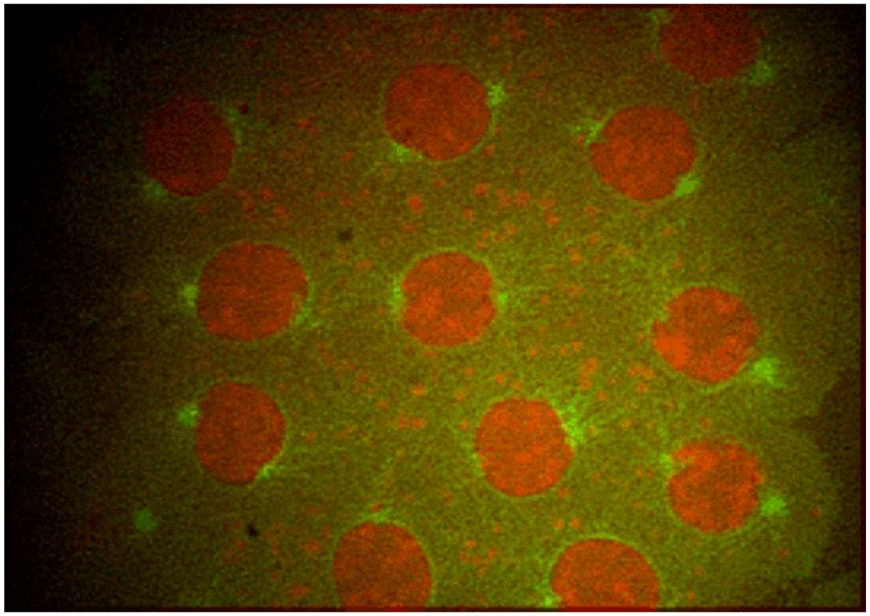
# Molecular Motors: Fuel Consumption and Force Production

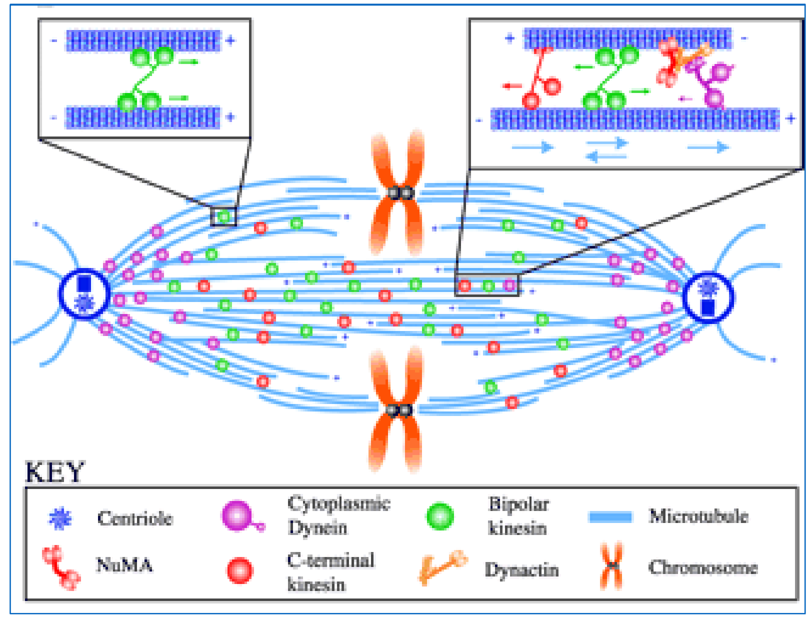
1. The chemical energy available from the hydrolysis of ATP is 100 X $10^{-21}$ J. How far can a motor protein exert a force of 5 pN before 100 X $10^{-21}$ J of work is done?

2. Molecular motor protein such as Kinesin can generate a force of typically 5 pN. Given that the viscosity of cytoplasm is 1000 times that of water and bacteria can be treated as a spherical object of radius $3/\pi$ $\mu$m , how fast could a single kinesin molecule move a bacterium through a cell cytoplasm?

*(Viscosity of water = 1 mPa.s)*

# Mitosis and Molecular Motors



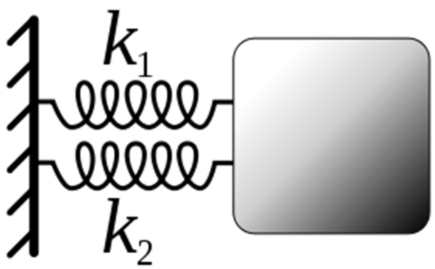


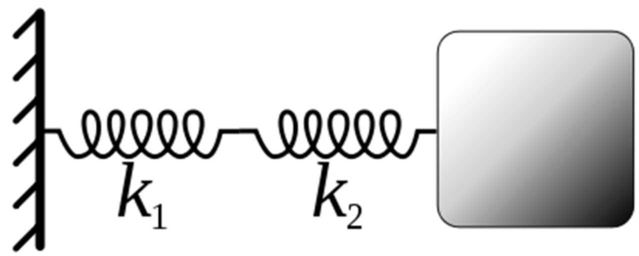

**3.** During mitosis, the chromosomes move several micrometers over the course of about 15 minutes. Calculate the average speed if distance moved is 30 $\mu$m. If the viscosity of the cytoplasm is 10000 times that of water, what force is required (assuming a size of a chromosome is same as a bacterium)? How many motors would be required to generate this force if force produced by each motor is 1.0 pN and forces are additive?

Video Source: [https://www.mcb.ucdavis.edu/faculty-labs/scholey/](https://www.mcb.ucdavis.edu/faculty-labs/scholey/)

Figure Source: Scholey JM, Rogers GC, Sharp DJ, J Cell Biol. 2001 Jul 23;154(2):261-266.

# Combinations of multiple springs and dashpots



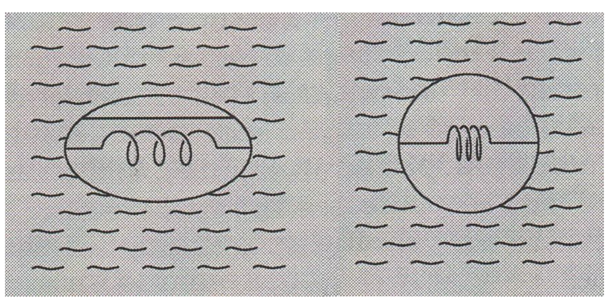

**4.** If springs are placed in parallel, show that their stiffnesses add. If they are placed in series, show that their compliances add (the compliance is reciprocal of the stiffness). If two dashpots are placed in parallel, show that the total drag coefficient is the sum of the individual coefficients. If the dashpots are placed in series, show that reciprocals of the drag coefficients add.

Figure Source: http://en.wikipedia.org/wiki/Series_and_parallel_springs#mediaviewer/File:SpringsInParallel.svg
Figure Source: http://en.wikipedia.org/wiki/Series_and_parallel_springs#mediaviewer/File:SpringsInSeries.svg

**5.** An oversimplified model of viscoelastic substance consists of a spring and a dashpot in series. When one end is held fixed and a constant force is abruptly applied to the other at time zero, how does the system move?

**6.** Suppose a water soluble protein is initially in a stretched conformation due some internal bonds such that its size is $x_s$. Suppose at t=0 these internal bonds break after adding a chemical. The protein then starts to undergo a conformational change to return to its relaxed state with size $x_0$. Find out an expression of x(t), where x(t) is the size of protein at time t after internal bonds break.

*(Hint: A mechanical model for such system would be a spring in parallel with a dashpot)*



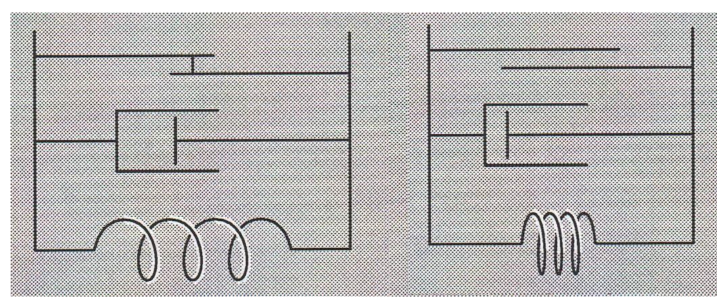


Figure Source: Mechanics of Motor Proteins and the Cytoskeleton, Jonathan Howard