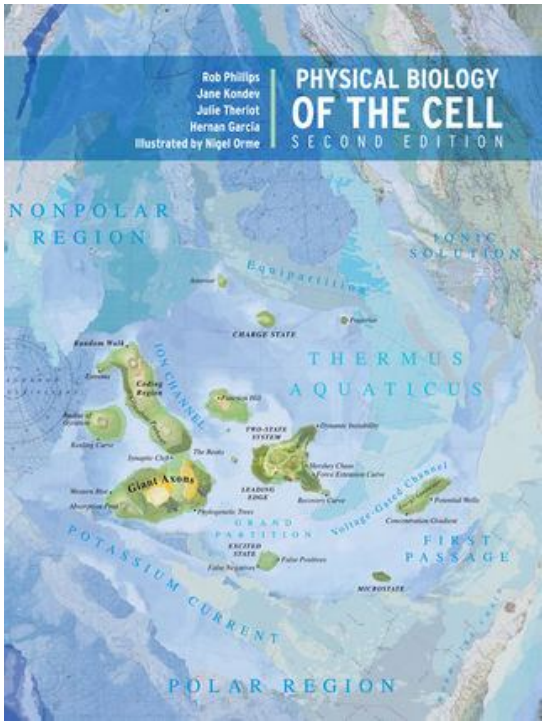
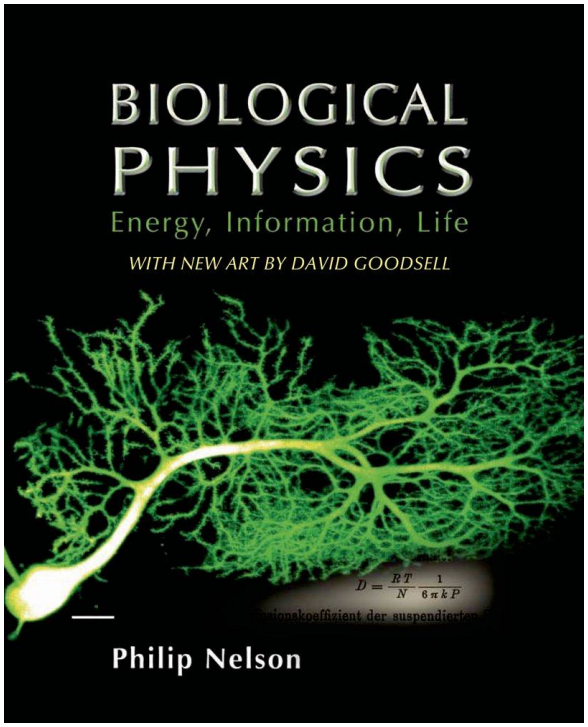
LECTURE 1

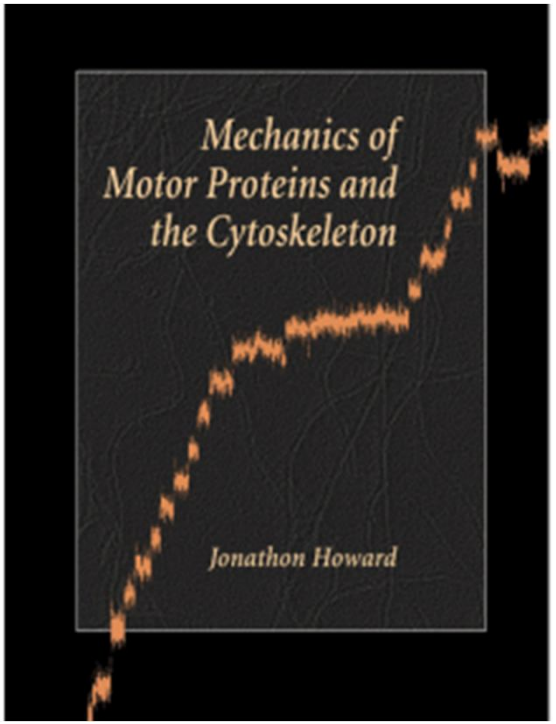
BB 101: MODULE II

PHYSICAL BIOLOGY

Most of the content of module II that we would discuss can be found in these books







1. Physical Biology of the cell, R. Phillips, J. Kondev, J. Theriot, H. Garcia (Publisher: Garland Science)

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

3. Mechanics of Motor Proteins and the Cytoskeleton, Jonathan Howard (Publisher: Sinauer Associates Inc.)

TEACHING ASSISTANTS

No	Roll No.	Name
1	134300005	Nandinee Giri
2	134303003	Anjali Anil
3	134303008	Apporava V
4	134300010	Anjneya Takshak
5	144300009	Uma Maheswari R
6	144303007	GUHAN.K.A
7	144309001	Sushant Kumar
8	144303010	Deborshi Chakraborty
9	134360004	Tanushree Roy

You learned many interesting biological phenomena in module I

What you are going to learn …

Physical Biology or Biophysics

A bridge between Biology and Physics

Source: http://www.biophysics.org/Education/WhatisBiophysics/tabid/2287/Default.aspx

Biology

- Biology studies life in its variety and complexity

- It describes how organisms go about getting food, sensing the environment, communicating, and reproducing

Source: http://www.biophysics.org/Education/WhatisBiophysics/tabid/2287/Default.aspx

Physics

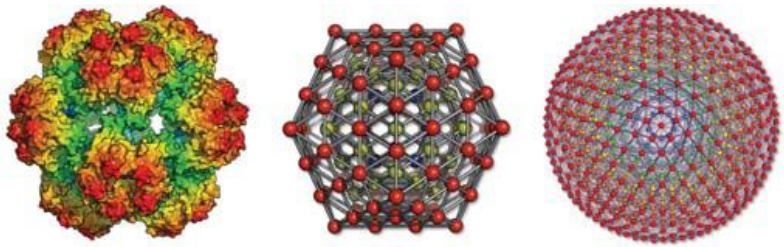
On the other hand, physics looks for mathematical laws of nature and makes detailed predictions about phenomenon that drive the systems

Source: http://www.biophysics.org/Education/WhatisBiophysics/tabid/2287/Default.aspx

Physical Biology or Biophysics

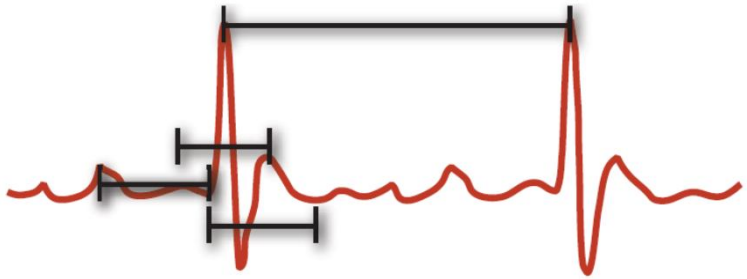
Look at the patterns in life and analyze them with math and physics to gain important insights

Virus



The natural symmetries of viral shell molecules contribute to their strength and flexibility. Properties are vital to their life cycles, also provide principles for devising strong, flexible materials

Electrocardiogram



The patterns and quantities in an electrocardiogram describe the functioning of the human heart.

Source: http://www.biophysics.org/Education/WhatisBiophysics/tabid/2287/Default.aspx

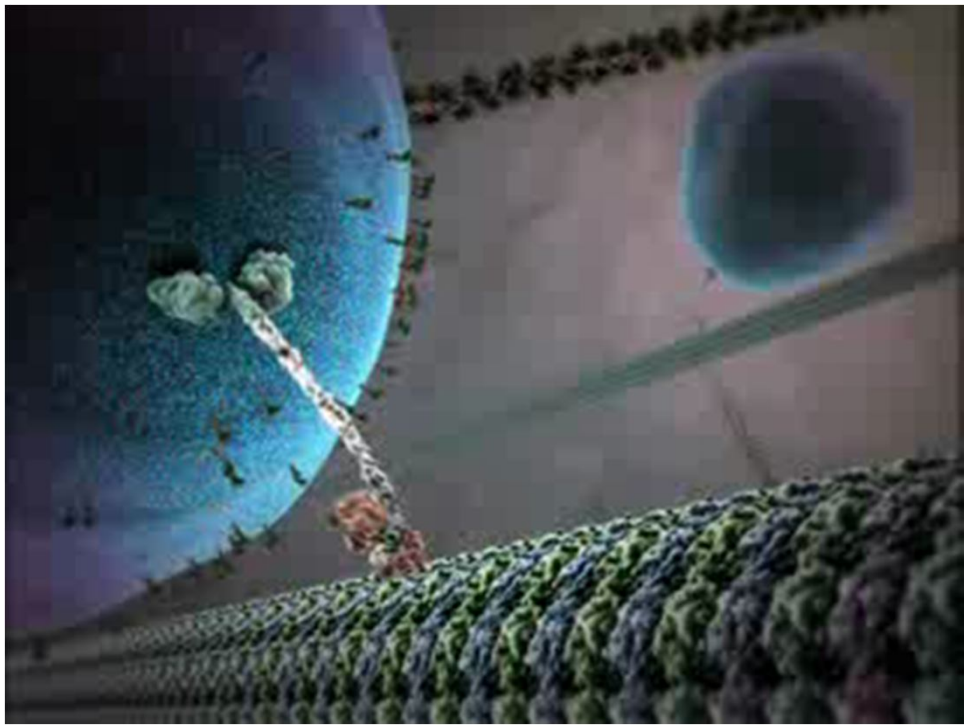
- Biophysics studies life at every level

- from atoms and molecules to cells, organisms, and environments

Source: http://www.biophysics.org/Education/WhatisBiophysics/tabid/2287/Default.aspx

How do protein machines work?

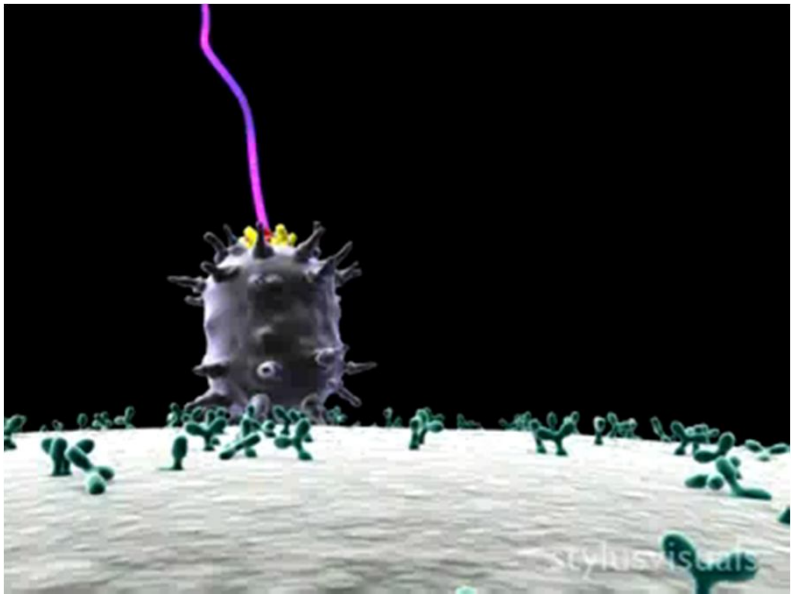
Millions of times smaller than everyday machines, molecular machines work on the same principles. They use energy to do work.

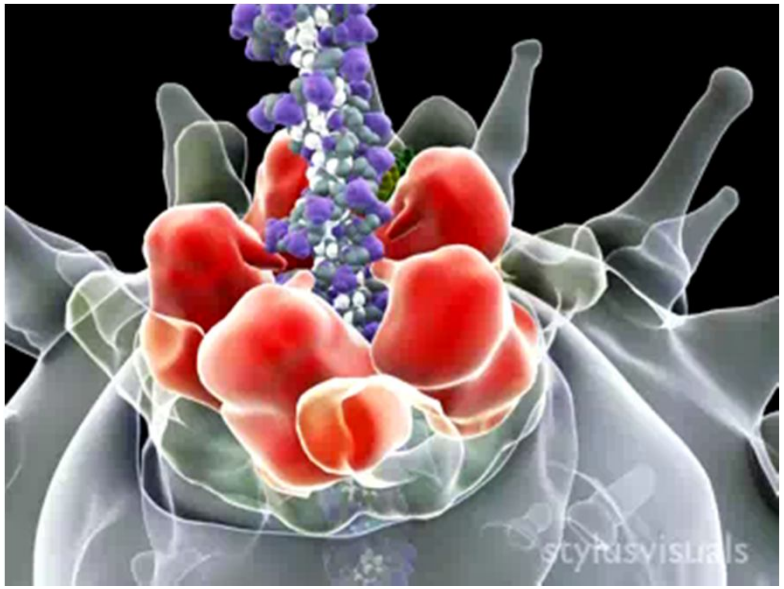


Insights gained may help you to design artificial nano-machines

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

How do proteins pack DNA into viruses?

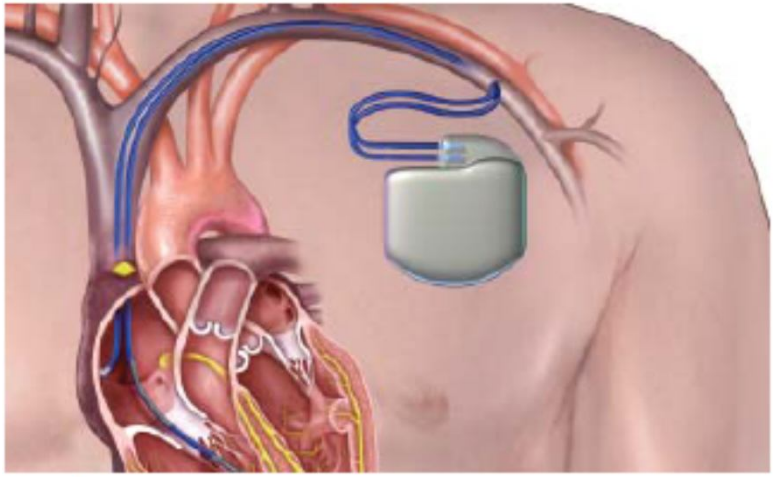




Insights gained may help you to design new therapeutic approaches to stop/treat viral infections

Video Sources:
https://www.youtube.com/watch?v=qKQwK3EB3oc
https://www.youtube.com/watch?v=H0xdDaWcrdk

What are technological applications?



implantable cardiac defibrillator

MRI

Biophysics provides insight and technologies based on the principles of physics and the mechanisms of biology

Source: http://www.biophysics.org/Education/WhatisBiophysics/tabid/2287/Default.aspx

In this part of the course…

- We'll attempt to provide a quantitative description of a few biological phenomena
- Why biological problems are among the most exciting physics problems
- Why biological problems are among the most challenging engineering problems

Let's start with proteins!!!

Physical Properties of a globular protein

Property	Value
Mass	166×10^{-24} kg
Density	1.38×10^{3} kg/m^3
Volume	120 nm^3
Radius	3 nm
Drag coefficient[a]	60 pN·s/m
Diffusion coefficient[a]	67 μm^2/s
Average speed[b]	8.6 m/s

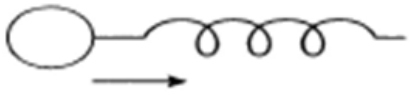
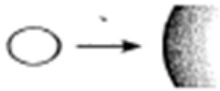
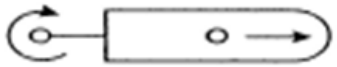
Magnitude of different forces acting on a proteins

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

What is force?

- Force is a push or pull
- Effect on free object (accelerate) and Effect on constrained object (deform)
- Net force is sum of all forces irrespective of their origin
- SI Unit of Force Newton
- What is 1N (weight of ? gram object)
- Forces at single molecule level are measured in pN (How small is 1 pN?)

Forces acting on a protein molecule

Type of force	Diagram	Approximate magnitude
Elastic		1–100 pN
		10,000 pN
Viscous		1–1000 pN
Collisional		10^{-12} to 10^{-9} pN for 1 collision/s
Thermal		100–1000 pN
Gravity		10^{-9} pN
Centrifugal		$< 10^{-3}$ pN
Magnetic		$<< 10^{-6}$ pN

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

Protein and other biomolecules

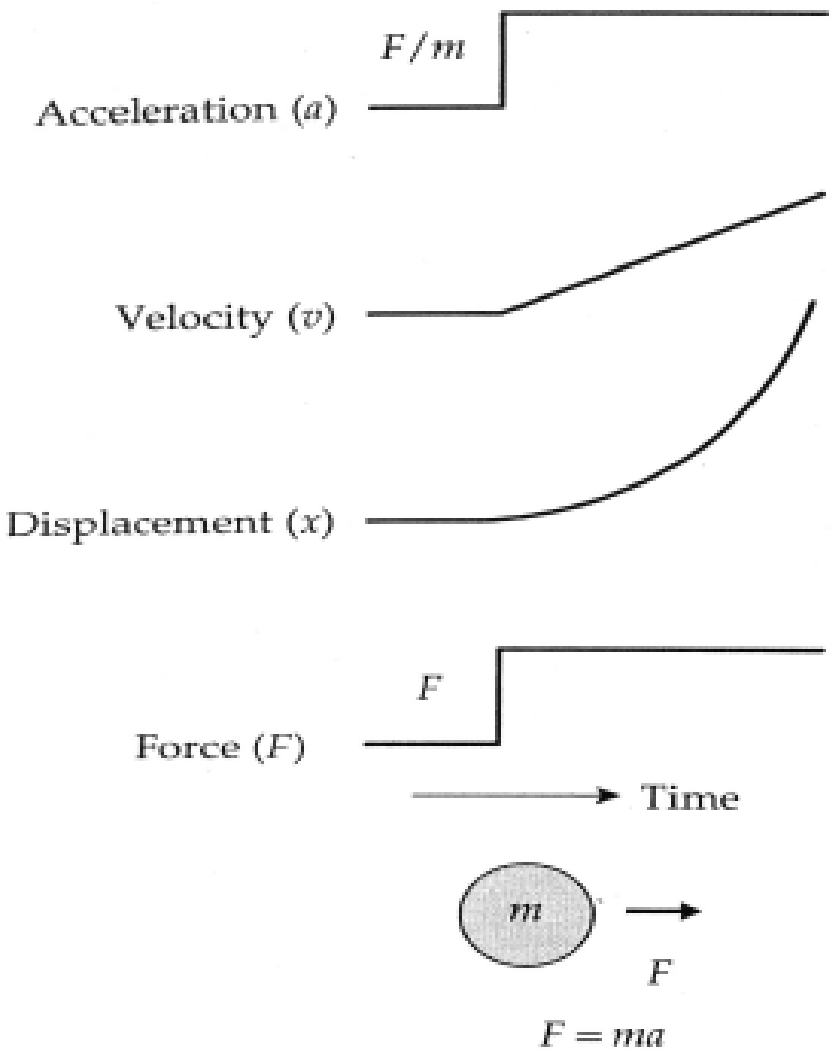
- Protein and other biomolecules are so tiny that inertial forces are very small in comparison to viscous forces due to surrounding medium

- Most of the mechanics discussed in standard school Physics text books is irrelevant at molecular and cellular levels as inertial forces are small

- Since effect of gravity can be ignored
- Oscillatory motions such as of pendulum and planets which occupy so much of mechanics textbooks, simply do not occur at level of single molecule

- However, we can still use mechanics to understand biological systems
- Some biological systems can be modelled as combinations of three fundamental mechanical elements mass, springs and dashpots
- Let’s review their properties

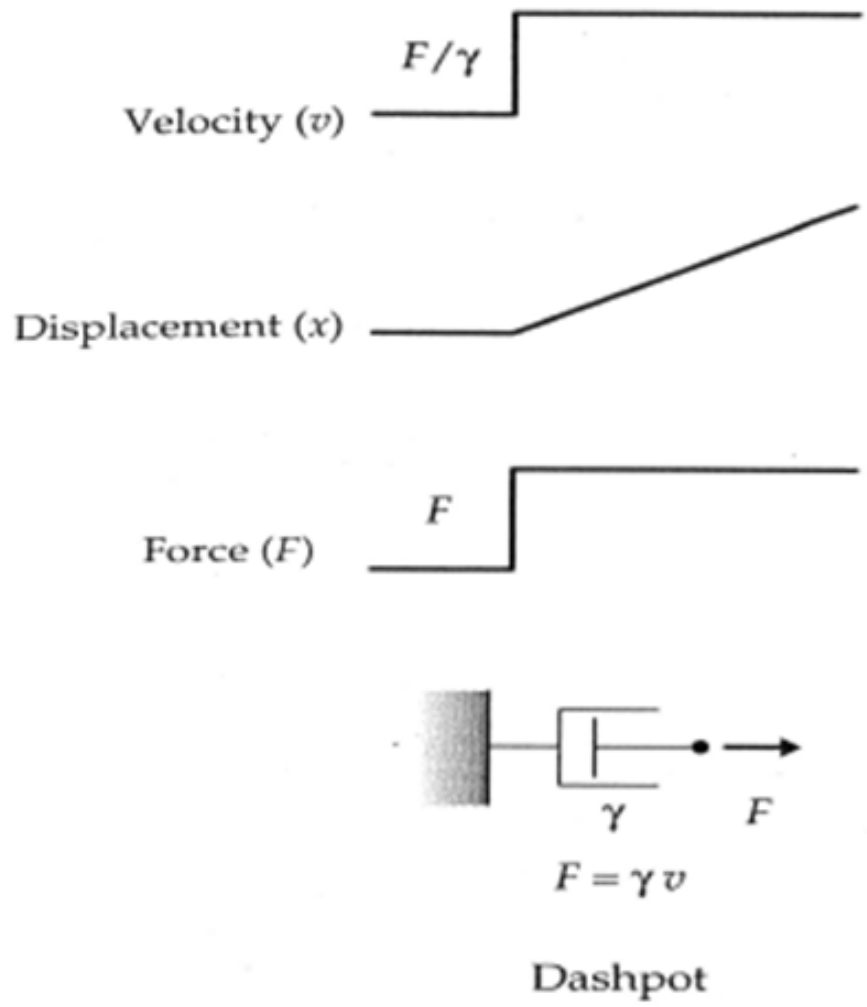
Motion of Mechanical element: Mass



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

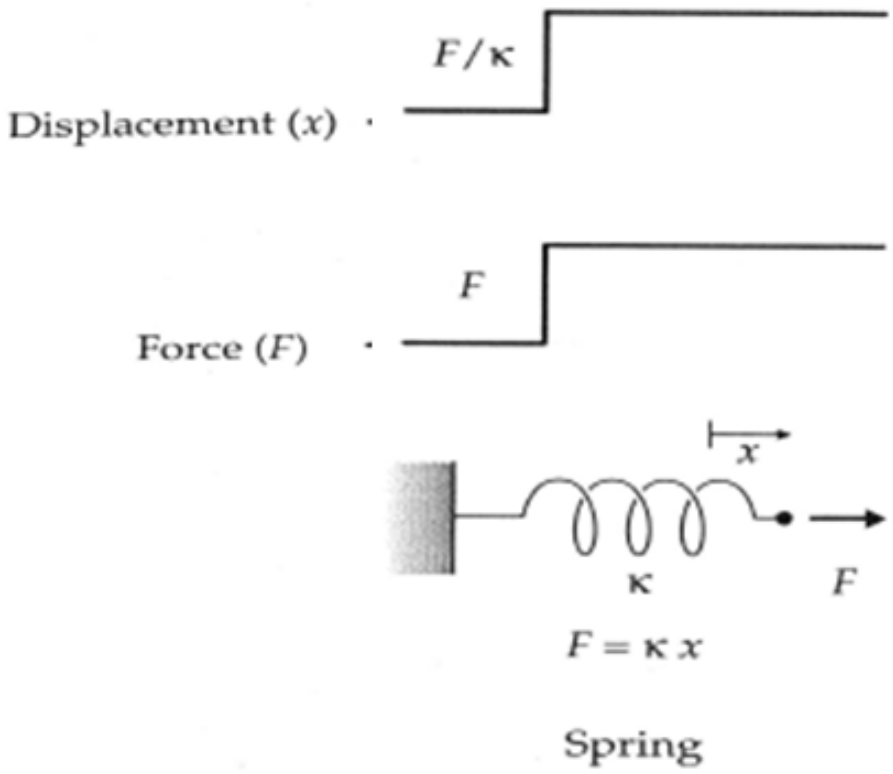
Motion of Mechanical element: Dashpot

- Responds to force by elongating at constant velocity
- No net force, external force is balanced by drag force
- Model to describe how object move in fluid (submerged object connected to dashpot)



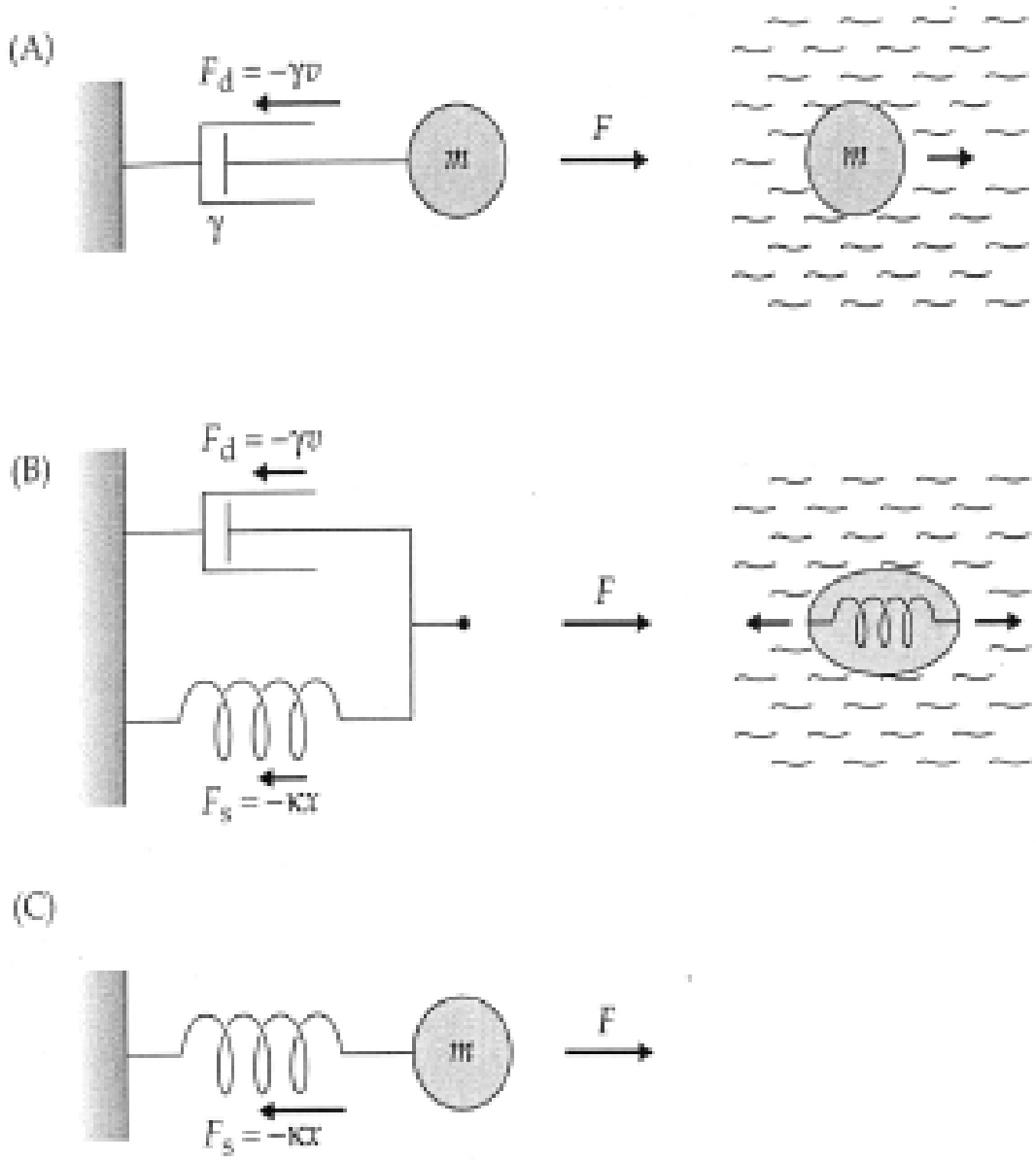
Source: Mechanics of Motor Proteins and the Cytoskeleton, Jonathan Howard

Motion of Mechanical element: Spring



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

Motion of combination of mechanical elements



Object damped by viscous fluid

Low mass object deformed in viscous fluid

Undamped objects

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

Motion of combination of mechanical elements

(A) Mass & Dashpot

$$m\frac{dv}{dt} + \gamma v = F$$

$$v(t) = \frac{F}{\gamma}[1 - exp(-\frac{t}{\tau})]$$

(B) Spring & Dashpot

$$\gamma\frac{dx}{dt} + \kappa x = F$$

$$x(t) = \frac{F}{\kappa}[1 - exp(-\frac{t}{\tau})]$$

(c) Mass & Spring

$$m\frac{d^2x}{dt^2} + \kappa x = F$$

$$x(t) = \frac{F}{\kappa}[1 - cos(\omega t)]$$

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

Summary

- *Physical Biology/Biophysics*
- *Why it is important*
- *Proteins molecules*
- *Inertial forces are negligible and effect of gravity can be ignored*
- *Many biological systems can be modeled as combination of three fundamental mechanical elements-mass, spring and dashpot*