

# LECTURE 1

## BB101: Course Instructors

First Half

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Second Half

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# TIMETABLE

## **BB101 - D3 & D4. RMALLIK. SPRING 2022-2023. LA-201.**

<b>DATE (DAY) 2023</b>	<b>11-12:30</b>	<b>2-3:30</b>
May 3 (Wed)	Lec1 (D3)	
May 7 (Sun)		Lec1 (D4)
May 9 (Tue)		Lec2 (D4)
May 10 (Wed)	Lec2 (D3)	
May 12 (Fri)	Lec3 (D3)	Lec3 (D4)
May 16 (Tue)		Lec4 (D4)
May 17 (Wed)	Lec4 (D3)	
May 19 (Fri)	Lec5 (D3)	Lec5 (D4)
May 23 (Tue)		Lec6 (D4)
May 24 (Wed)	Lec6 (D3)	
May 26 (Fri)	Lec7 (D3)	Lec7 (D4)
May 30 (Tue)		Lec8 (D4)
May 31 (Wed)	Lec8 (D3)	
Jun 2 (Fri)	Lec9 (D3)	Lec9 (D4)
Jun 6 (Tue)		Lec10 (D4)
Jun 7 (Wed)	Lec10 (D3)	
Jun 8 (Thu)	Lec11 (D3)	Lec11 (D4)

NOTE:- On Thursday, 08/06/2023, timetable of Friday will be followed.

### **TUTORIALS, TA-Meetings, QUIZ AND ENDSEM EXAM**

**May 8 (Mon) 1pm-2pm TA meeting**

May 9 (Tue) 11:35-12:30 Tutorial of Lec1 for D4

May 11 (Thu) 8:30-9:25 Tutorial of Lec1 for D3

May 16 (Tue) 11:35-12:30 Tutorial of (Lec2+Lec3) for D4

May 18 (Thu) 8:30-9:25 Tutorial of (Lec2+Lec3) for D3

**May 22 (Mon) 1pm-2pm TA meeting**

May 23 (Tue) 11:35-12:30 Tutorial of (Lec4+Lec5) for D4

May 25 (Thu) 8:30-9:25 Tutorial of (Lec4+Lec5) for D3

**May 29 (Mon) 1pm-2pm TA meeting**

May 30 (Tue) 11:35-12:30 Tutorial of (Lec6+Lec7) for D4

**May 31 (Wed) 8-9:30AM Quiz for D3 and D4**

June 1 (Thu) 8:30-9:25 Tutorial of (Lec6+Lec7) for D3

June 6 (Tue) 11:35-12:30 Tutorial of (Lec8+Lec9) for D4

June 8 (Thu) 8:30-9:25 Tutorial of (Lec8+Lec9) for D3

June 10,11 (Sat,Sun) Tutorial of (Lec10+Lec11) for D3 and D4

**June 12 (Mon) 1pm-2pm TA meeting**

**EndSem Exams Week of 12 June**

EndSem Evaluation Week of 19 Jun

## TUTORIALS

- ❖ 2 Lectures : 1 Tutorial
- ❖ Will pose Questions at the end of Lectures and suggest a Research paper/Online Video. Students can read up and discuss with the TA during Tutorial.
- ❖ Reading Research Papers is Optional. You will not be asked any questions in Exams/Quiz that are based on Research papers.
- ❖ Students can seek other clarifications about the Lectures from TA

## QUIZ AND ENDSEM EXAMS

- ❖ Paper-based
- ❖ Mix of Descriptive, Multiple-choice, T/F
- ❖ No Computer, Phone, Internet
- ❖ Quiz : May 31<sup>st</sup> (8-9:30 AM).
  - Only Questions from the part taught by R. Mallik
  - 10% Weightage for the part taught by R. Mallik
- ❖ EndSem : Week of 12 June.
  - Only Questions from the part taught by R. Mallik
  - 90% Weightage for the part taught by R. Mallik

# BUILDING A LIVING MACHINE

## SECTION 1 MOLECULES, FORCE AND MOTION

Lecture 1 Proteins as Machines

Lecture 2 Linear Motors

Lecture 3 Rotary Motors

Lecture 4 Artificial Nano Machines

## SECTION 2 MOTION INSIDE CELLS

Lecture 5 The Dynamic Cytoskeleton - Microtubules

Lecture 6 The Dynamic Cytoskeleton - Actin

## SECTION 3 MOTION OF CELLS

Lecture 7 Bacterial propulsion - Chemotaxis

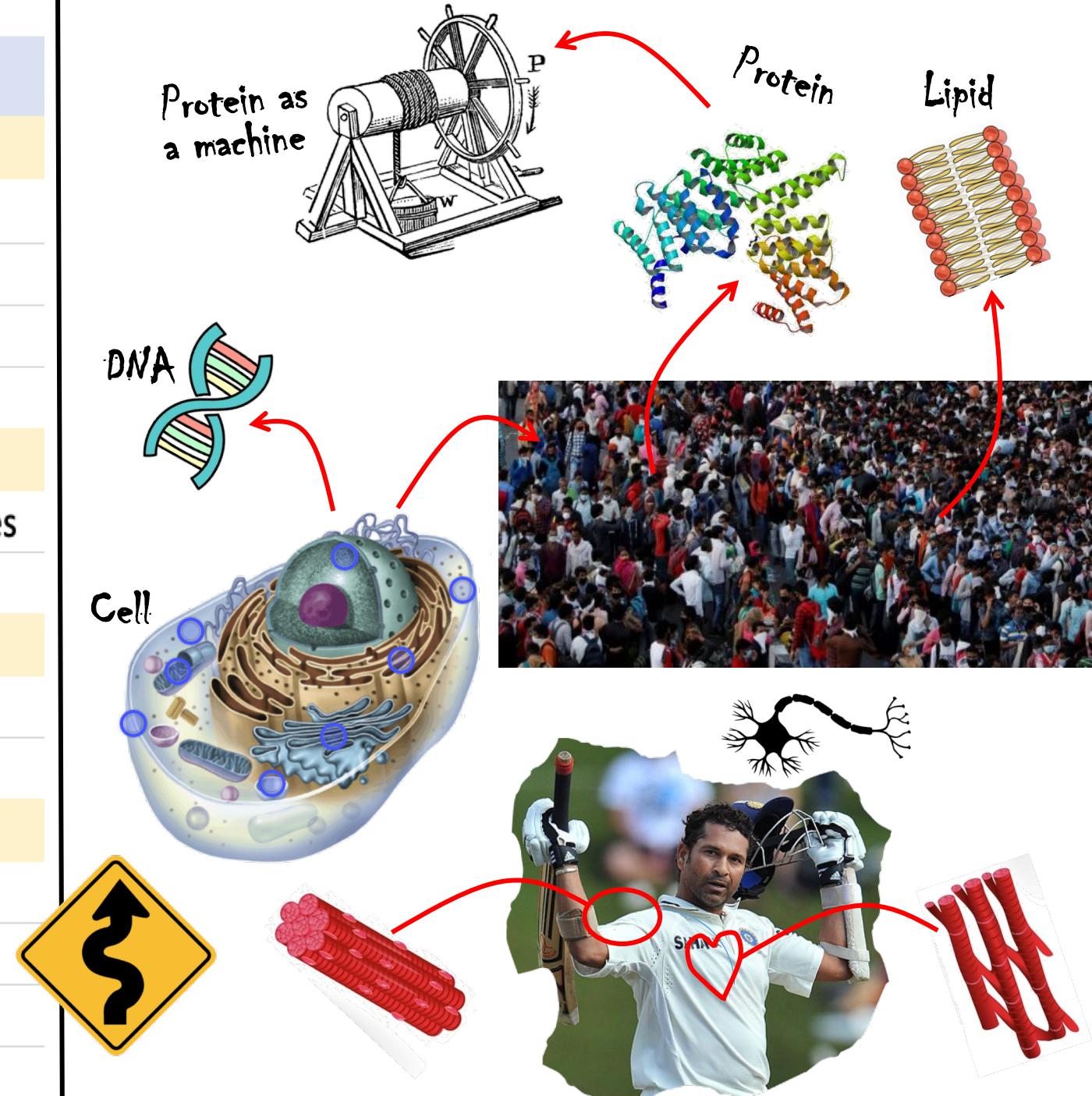
Lecture 8 Beating of Cilia

## SECTION 4 MOTION IN ANIMALS

Lecture 9 Muscle Contraction

Lecture 10 Heartbeats

Lecture 11 To Sing or to Fly

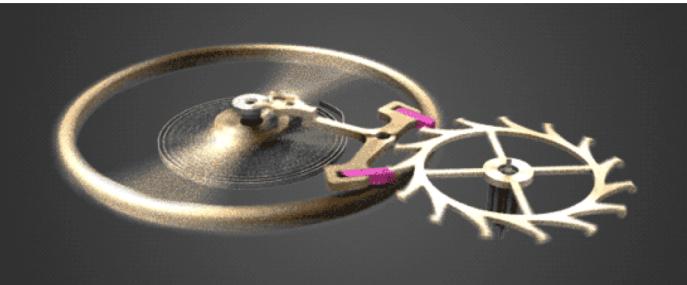


## What is a Machine ? Can we think of a Protein as a Machine ?

- A machine is anything that reduces human effort.
- Machines are any combination of bodies so connected that their relative motions are constrained, and by which means force and motion may be transmitted and modified, ....

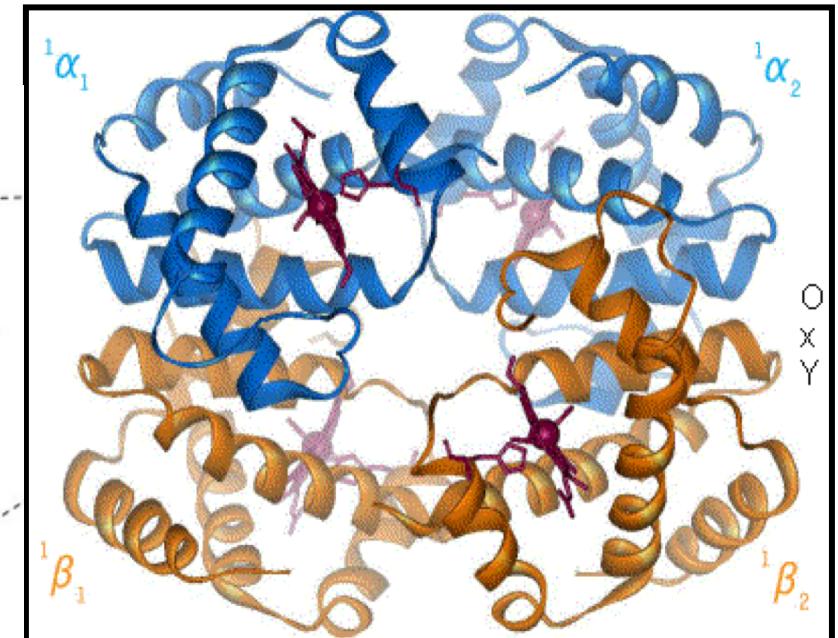
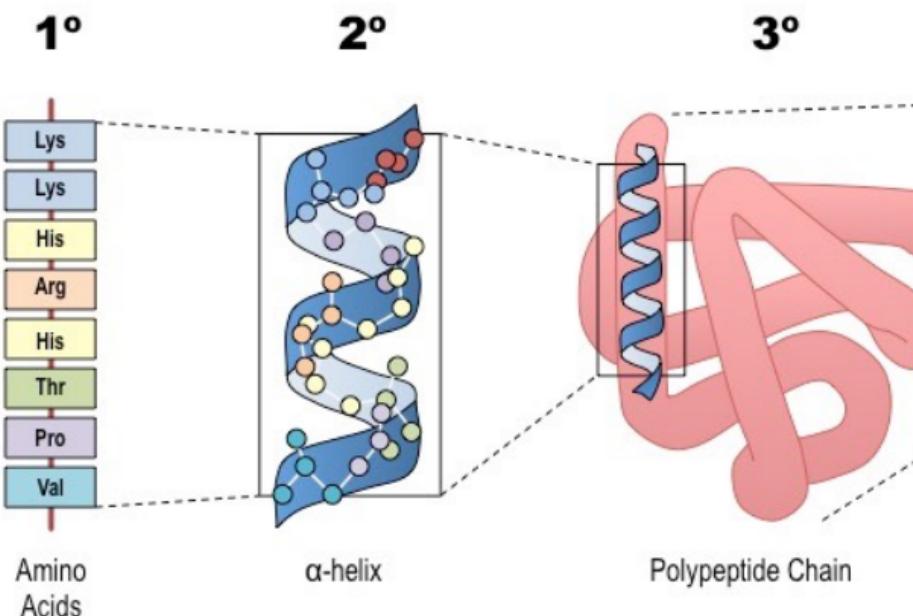


What makes  
the watch tick ?



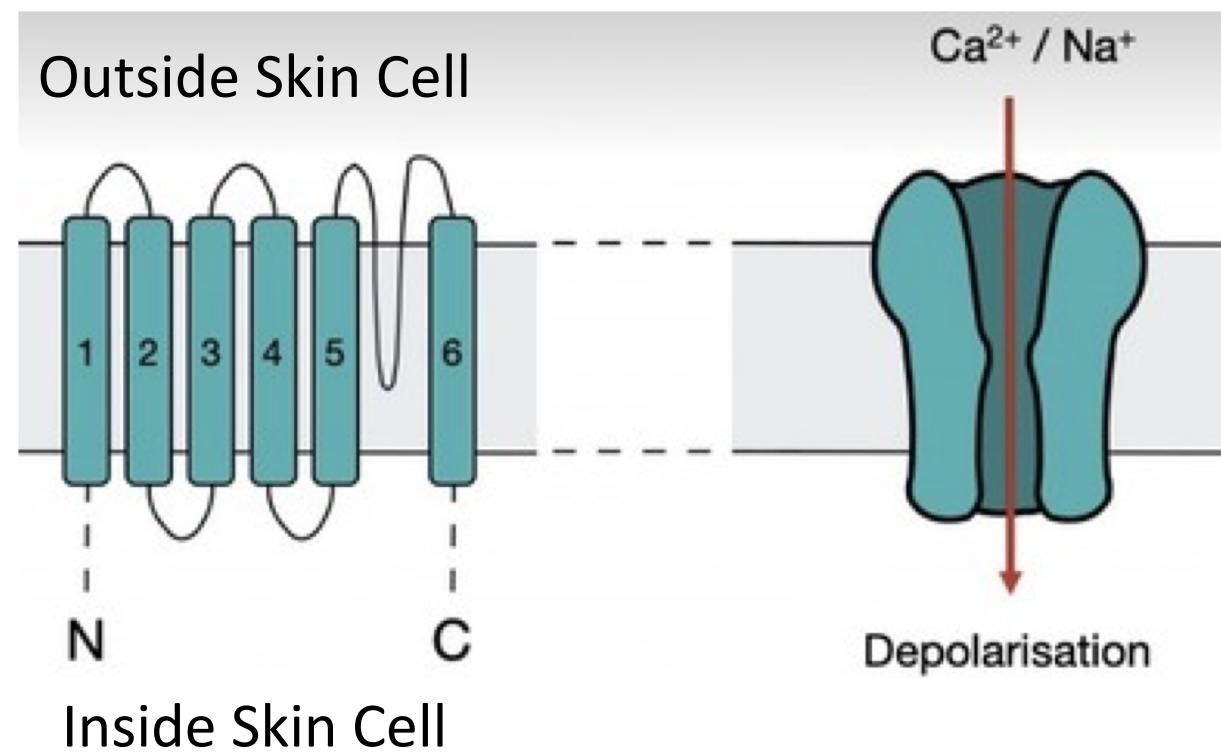
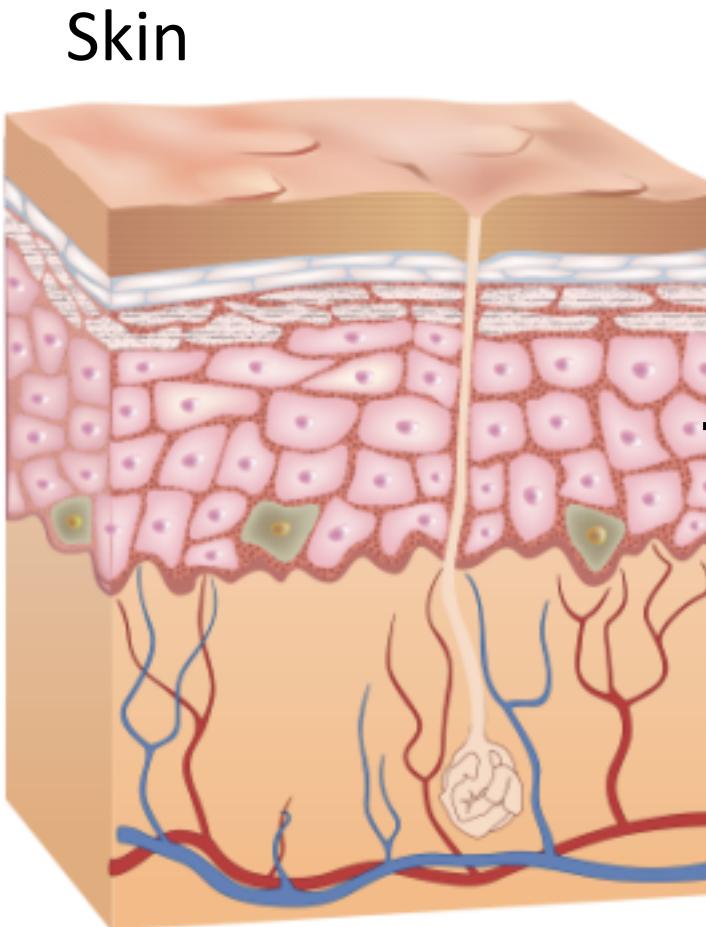
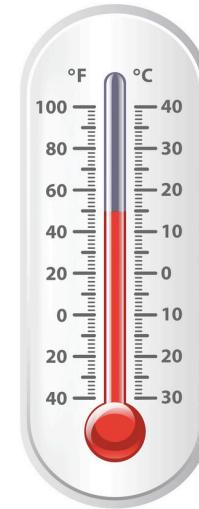
Protein that carries oxygen  
and makes your blood red

What makes  
you tick ?



# Where is your “Thermometer” ??

Protein Machines that Sense Temperature  
Transient Receptor Potential (TRP) ion channels.



TRP channels are a Family of Proteins :– Different members are adapted to do different Jobs

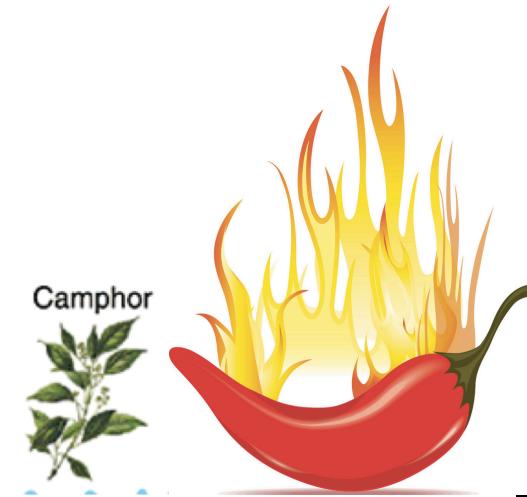
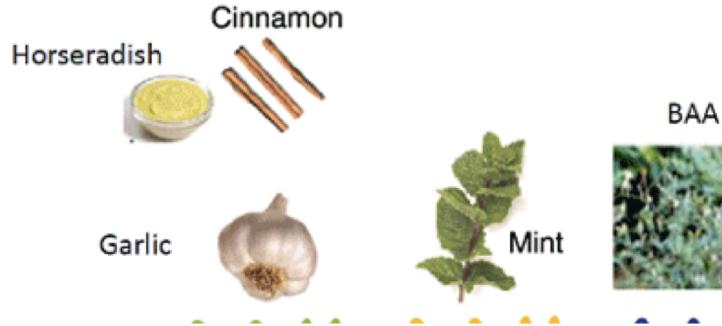
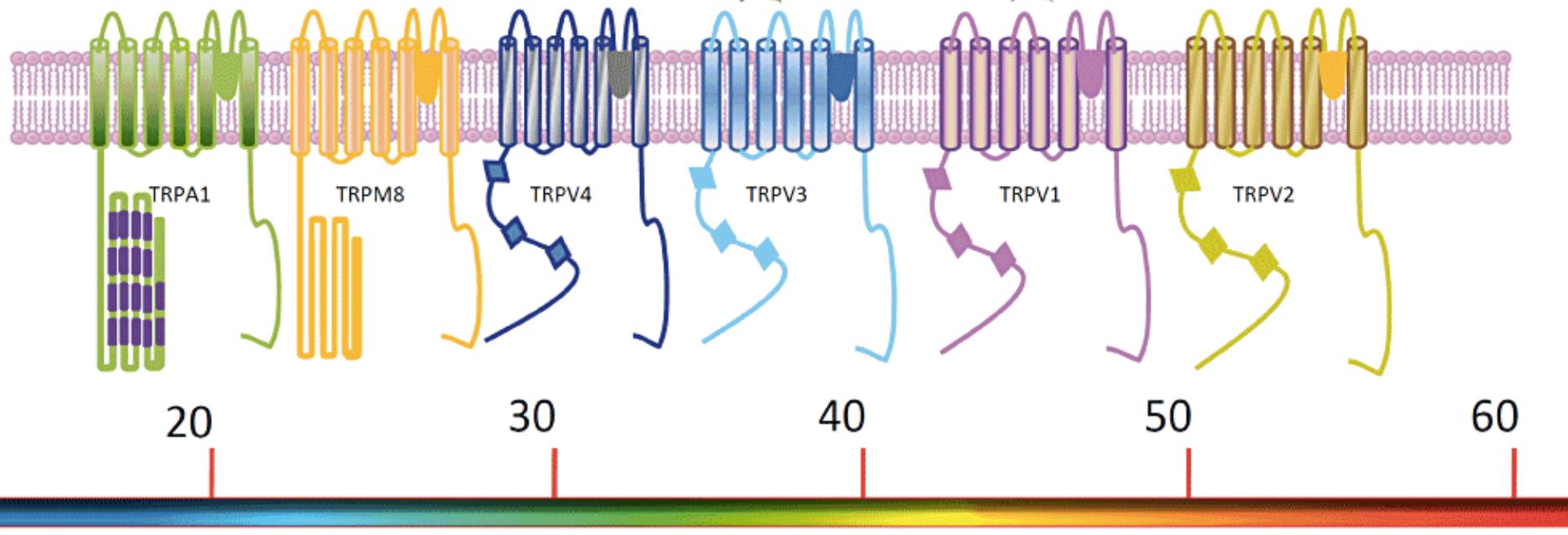
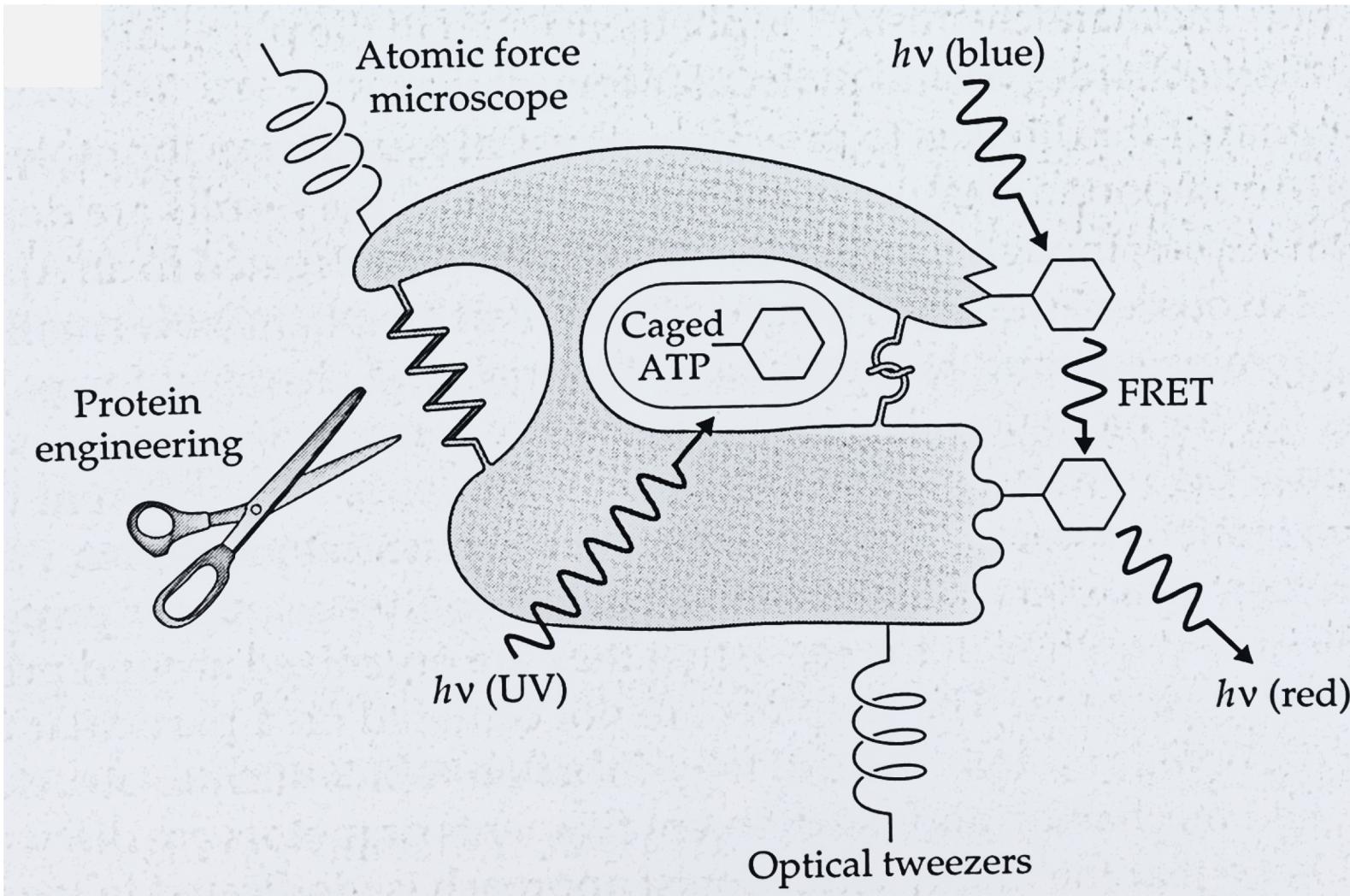


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www.alamy.com



TRP Channels  
are also  
targets for  
pain  
medicines

## A “Protein Machine” and how to study it

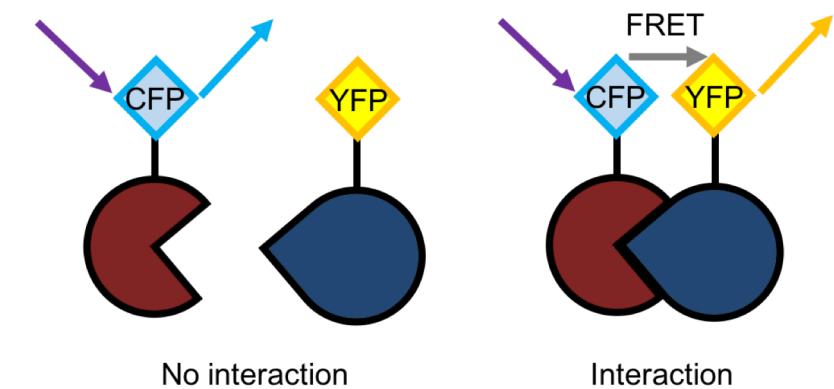


More information

### FRET :- Fluorescence Energy Transfer

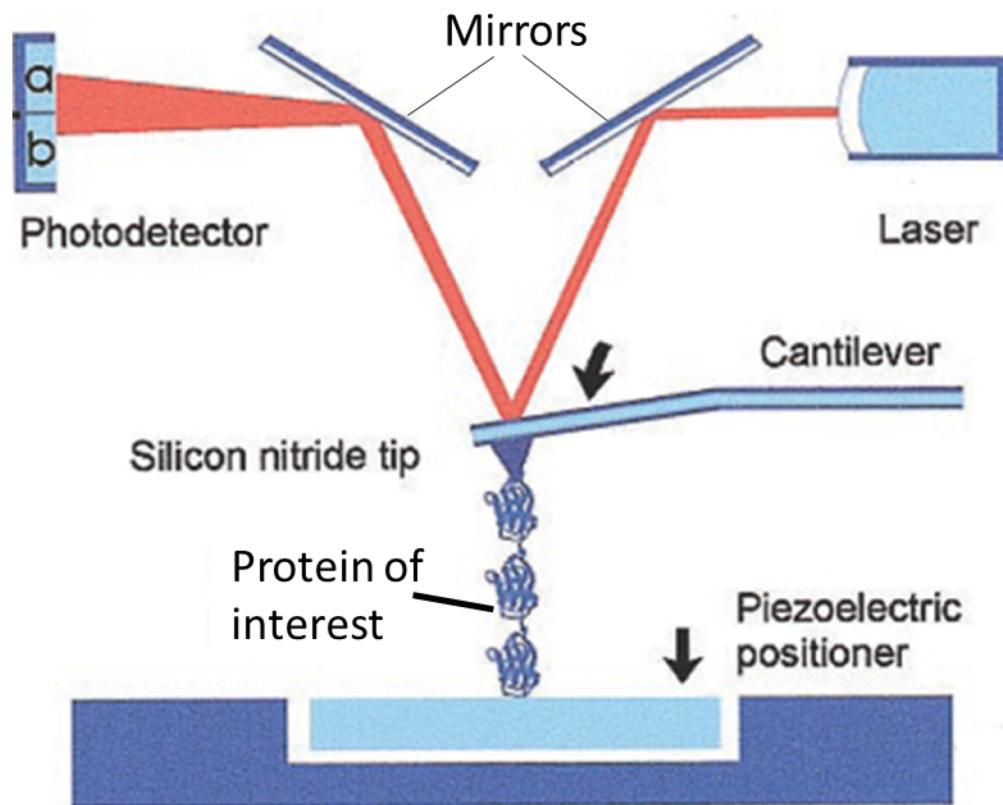
FRET experiment can be done to see if two parts of the same protein are interacting

Or, also to see if two proteins are interacting :-



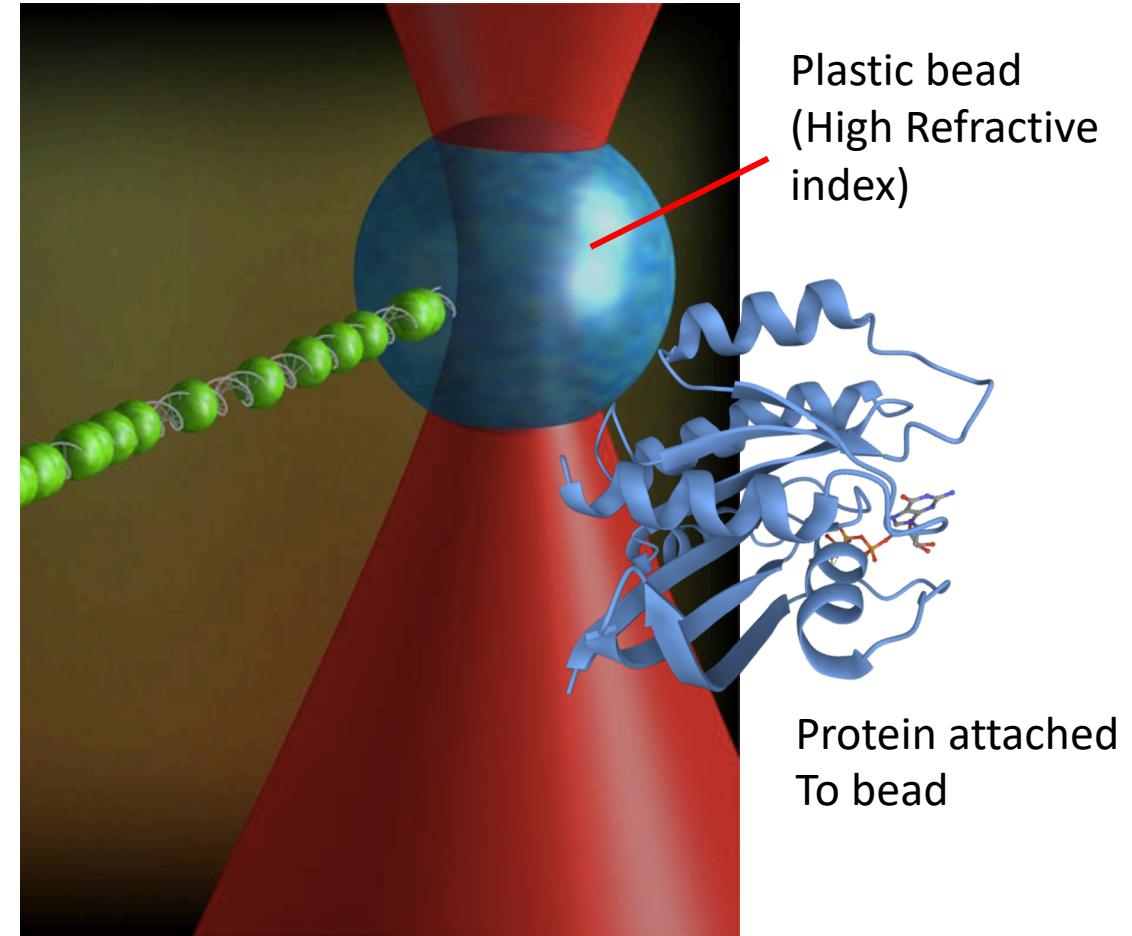
After J. Howard,  
Mechanics of Motor Proteins and the Cytoskeleton

## Atomic Force Microscope

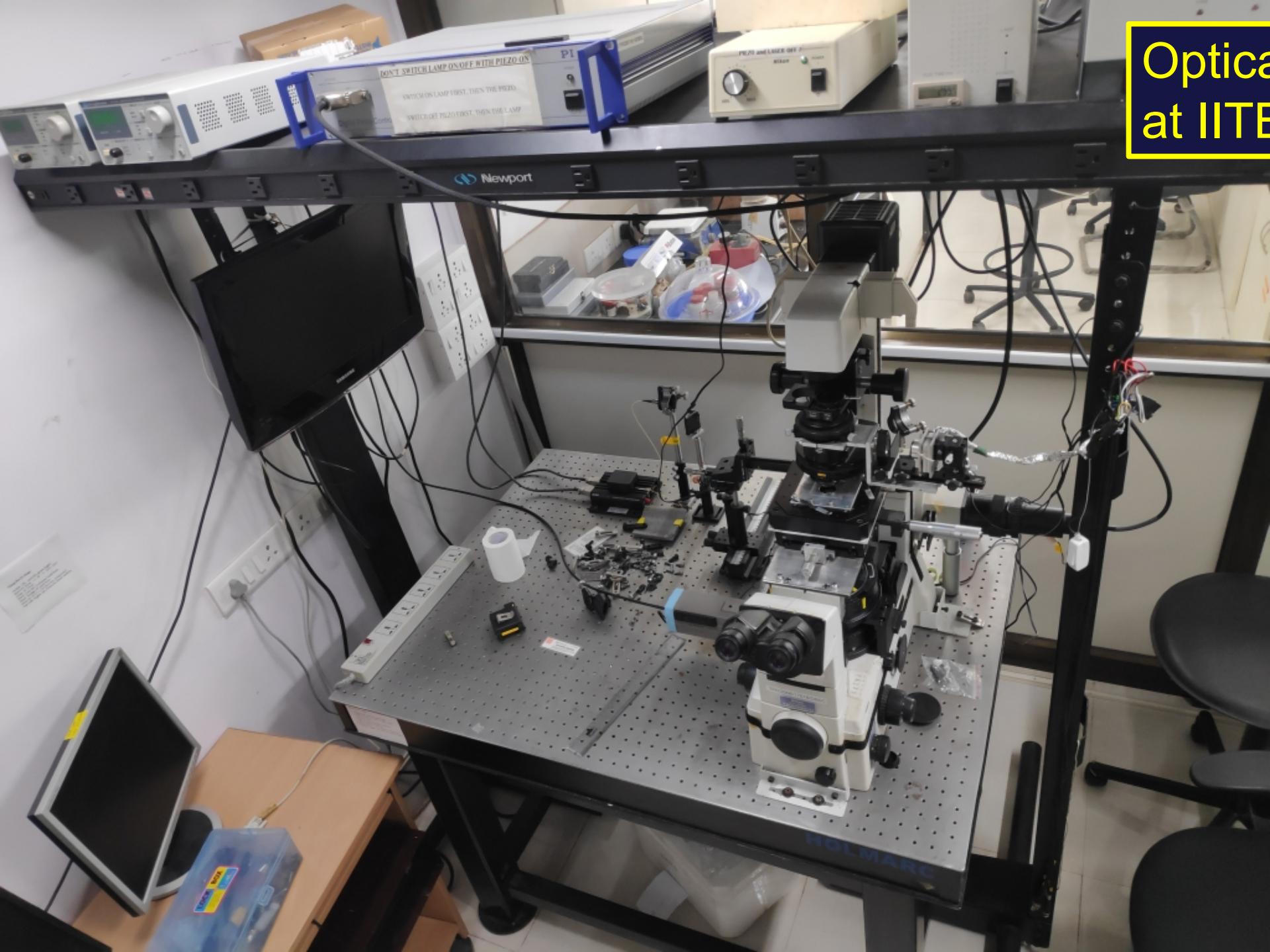


*Adapted from Paul Hansma website*

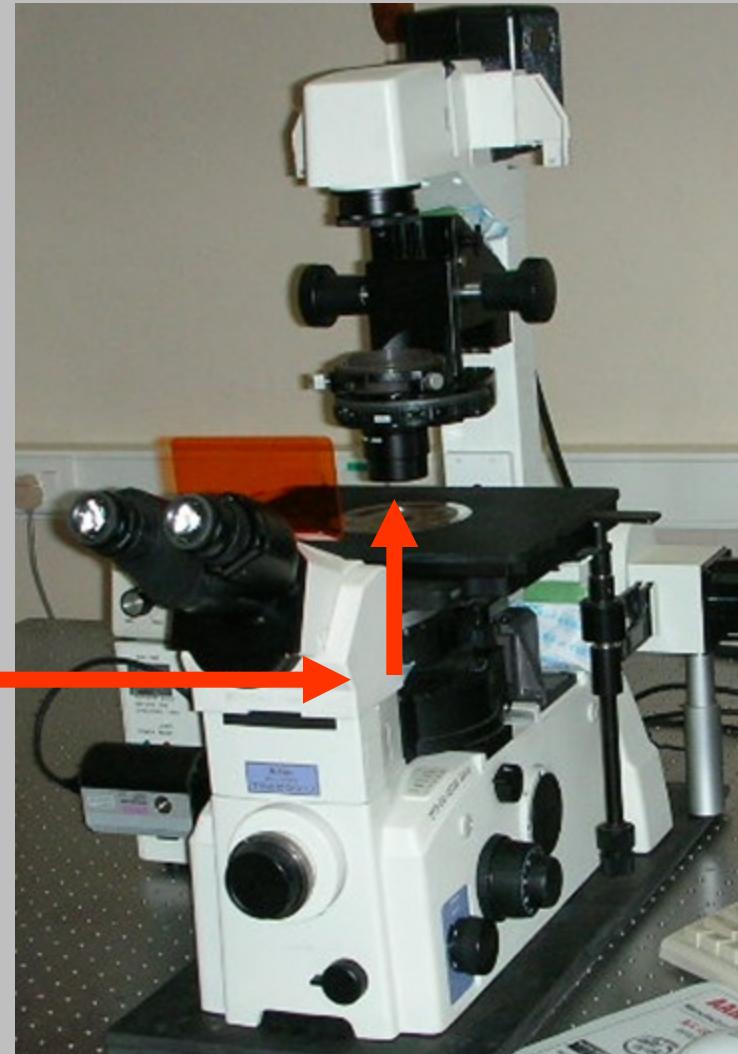
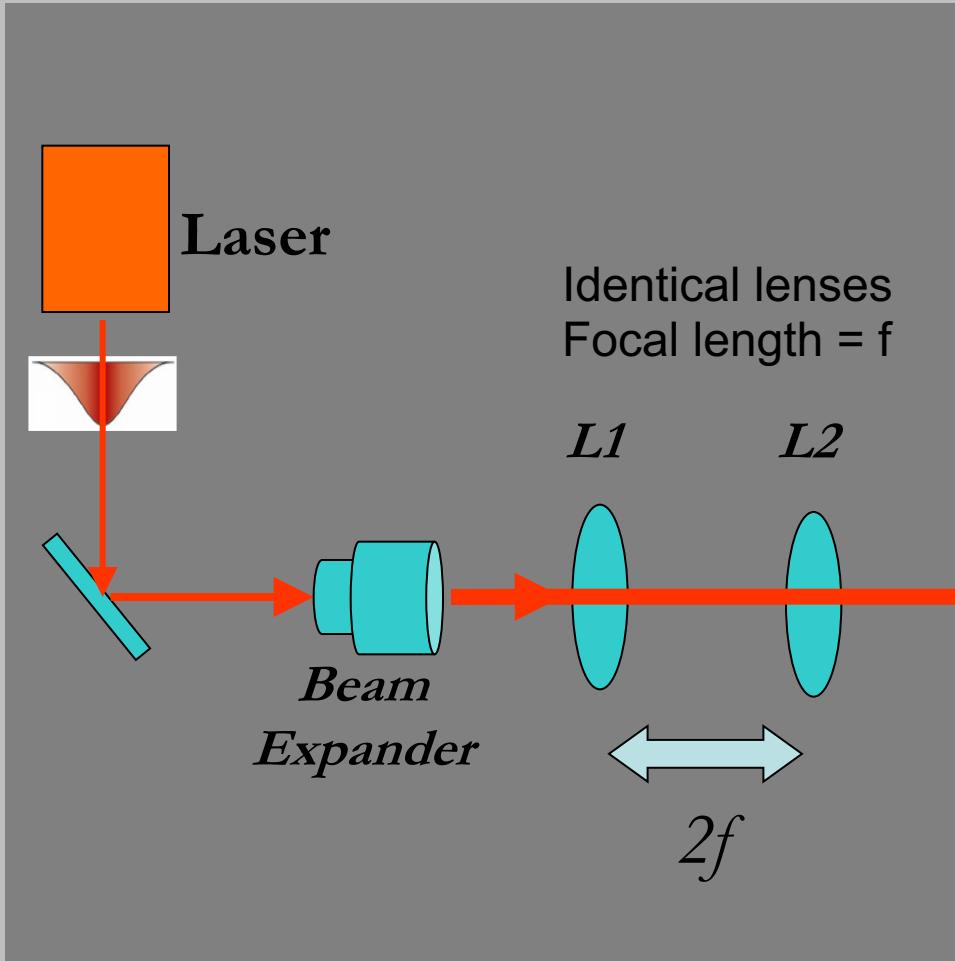
## Optical Tweezer



# Optical Trap at IITB



# The simplest Optical trap ...





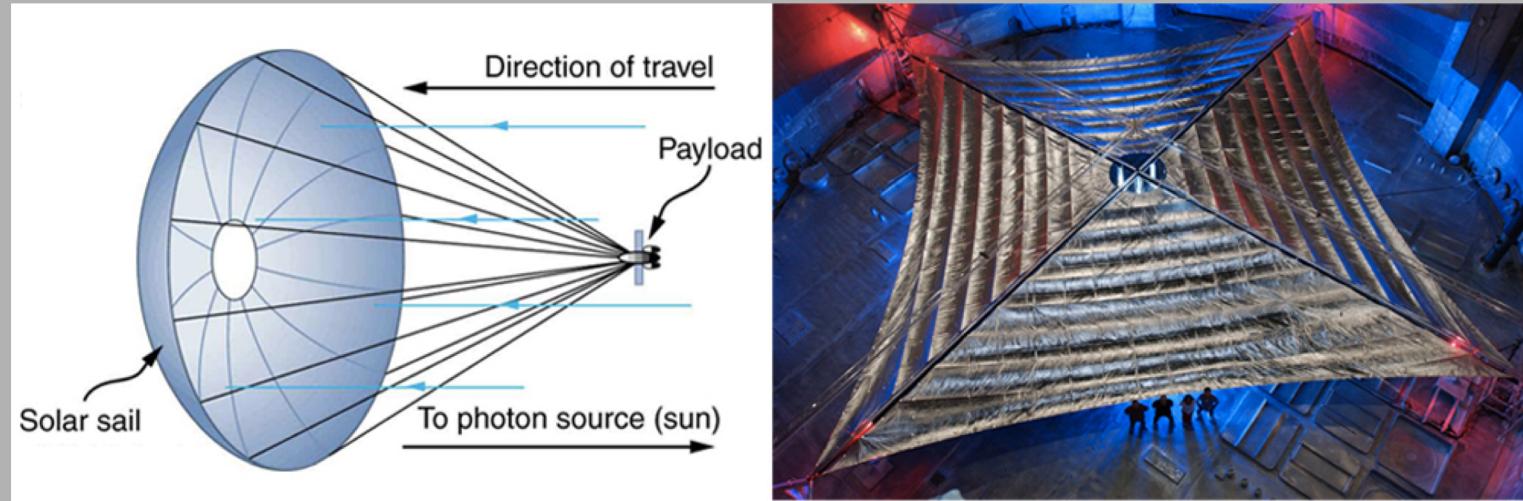
# RADIATION PRESSURE

Photon

$$p = hf/c = h/\lambda$$



Near-Earth  
Asteroid  
Scout



Single photon momentum  $\sim 10^{-27}$  kg m/sec

Laser pointer (mW)  $\sim 10^{15}$  photons/sec

$dp/dt \sim 10^{-12}$  Newtons (Pico Newtons)

# How does it work ?

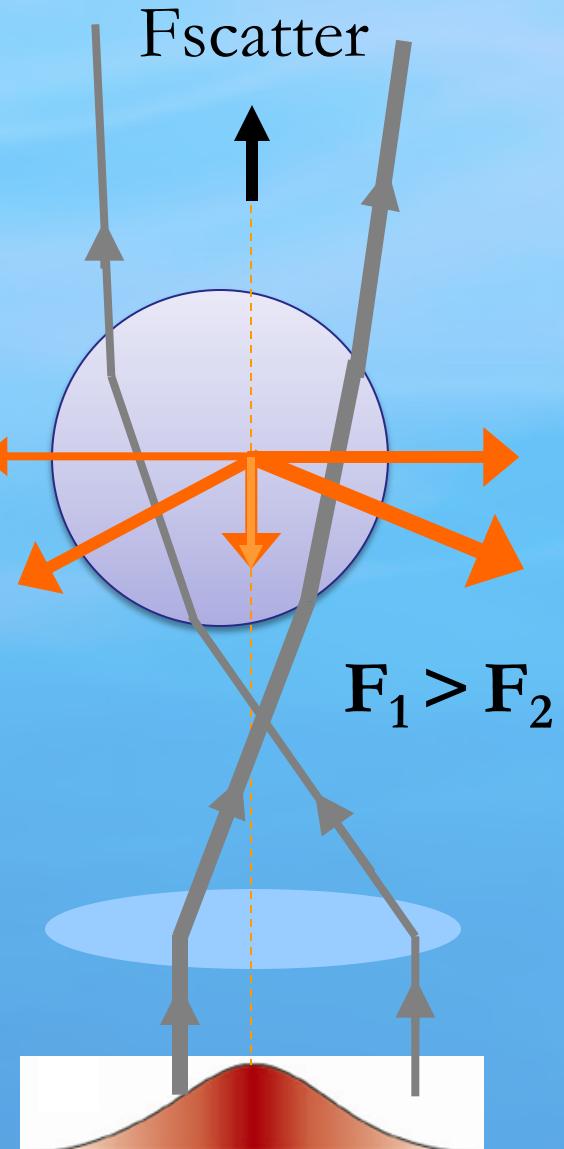
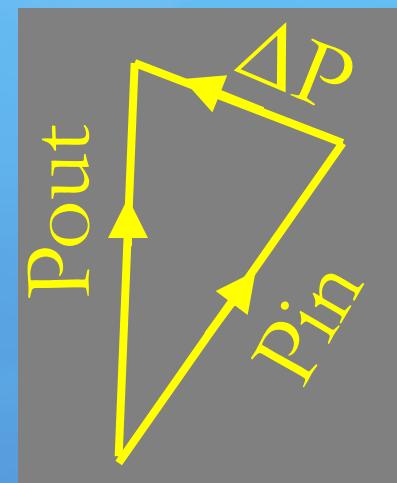
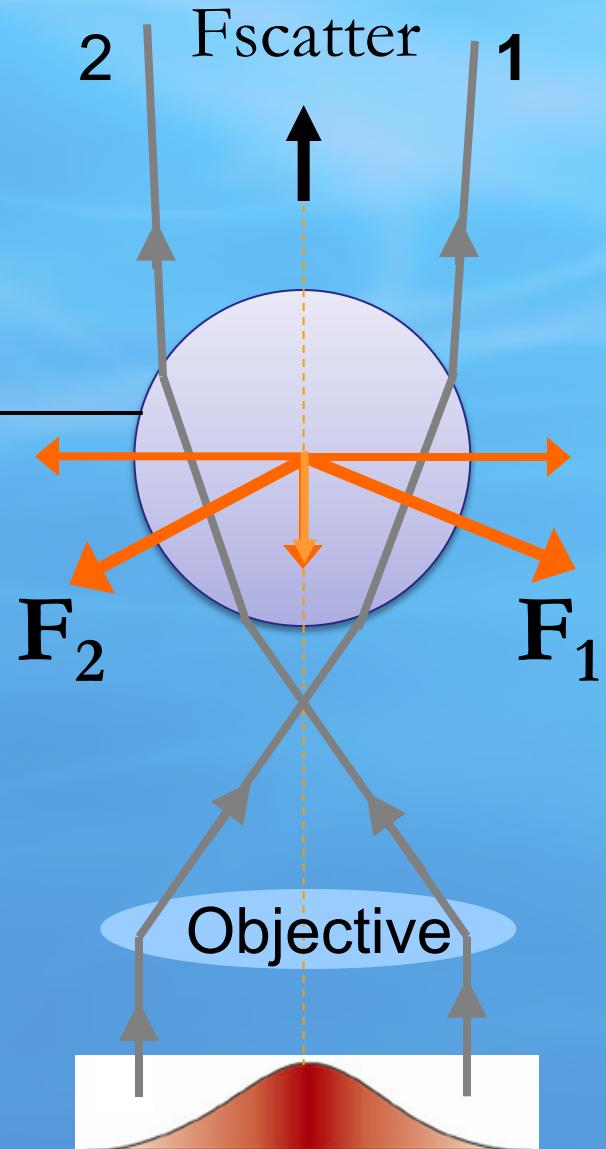
Imagine “running” onto a boat and then jumping off

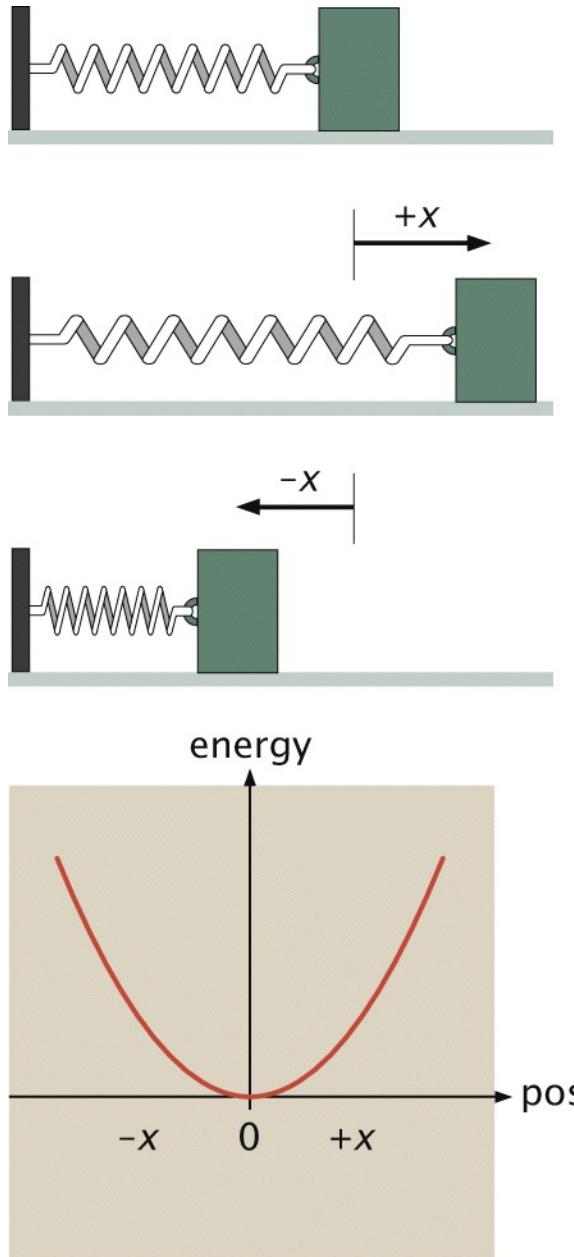
Photons

$$p = hf/c = h/\lambda.$$

Water  
Outside  
Refractive  
Index (RI)  
= 1.33

Trap Micron  
Sized object  
of Higher  
RI (= 1.5)





## FOR PROTEIN

A little more Complicated, but the idea is the same

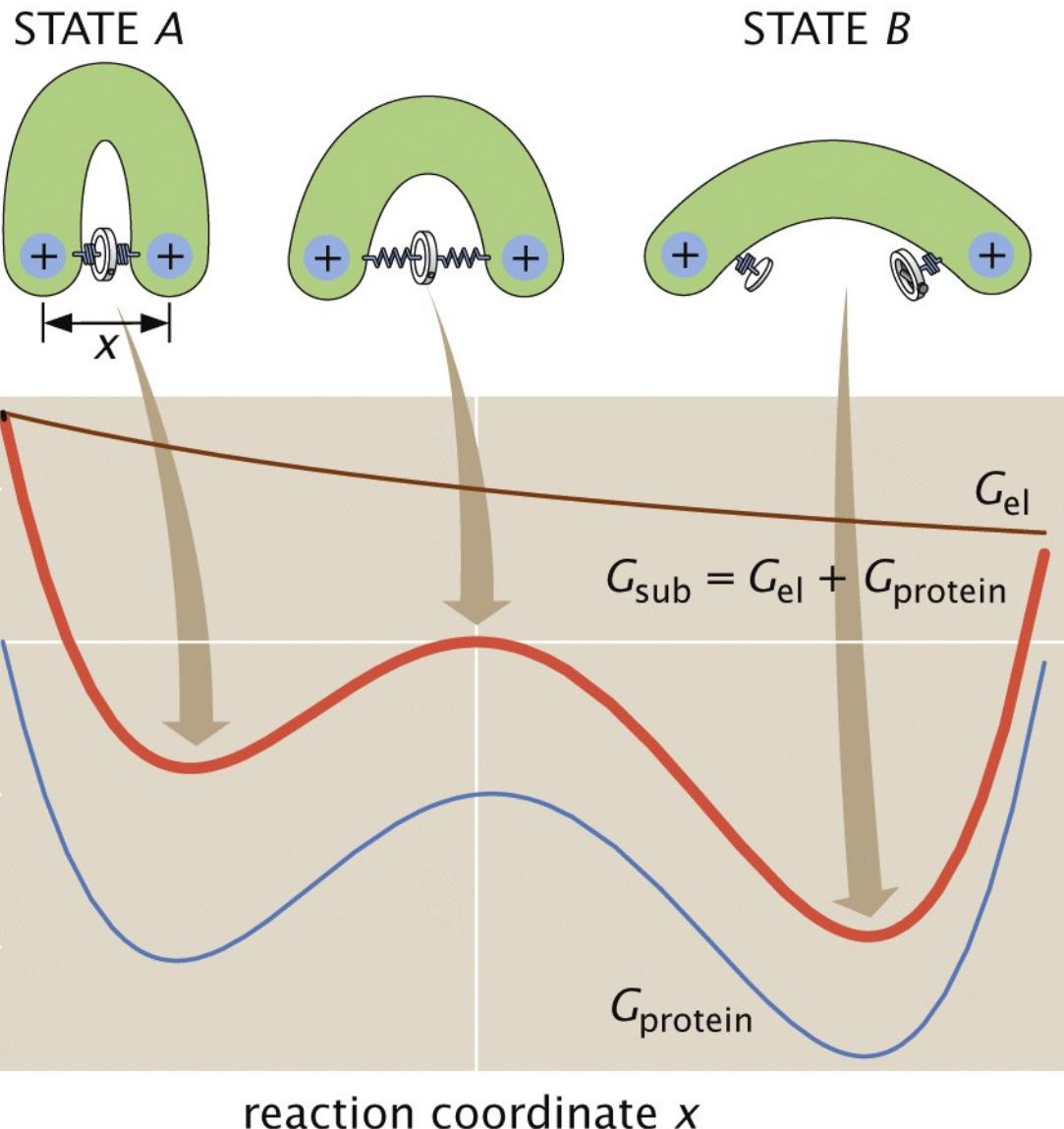
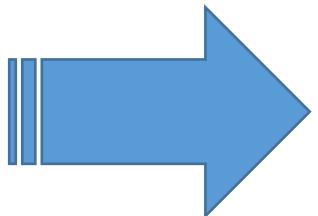


Figure 1.12a Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Figure 3.30a Physical Biology of the Cell, 2ed. (© Garland Science 2013)

# THE NANO SCALE IS SPECIAL ...

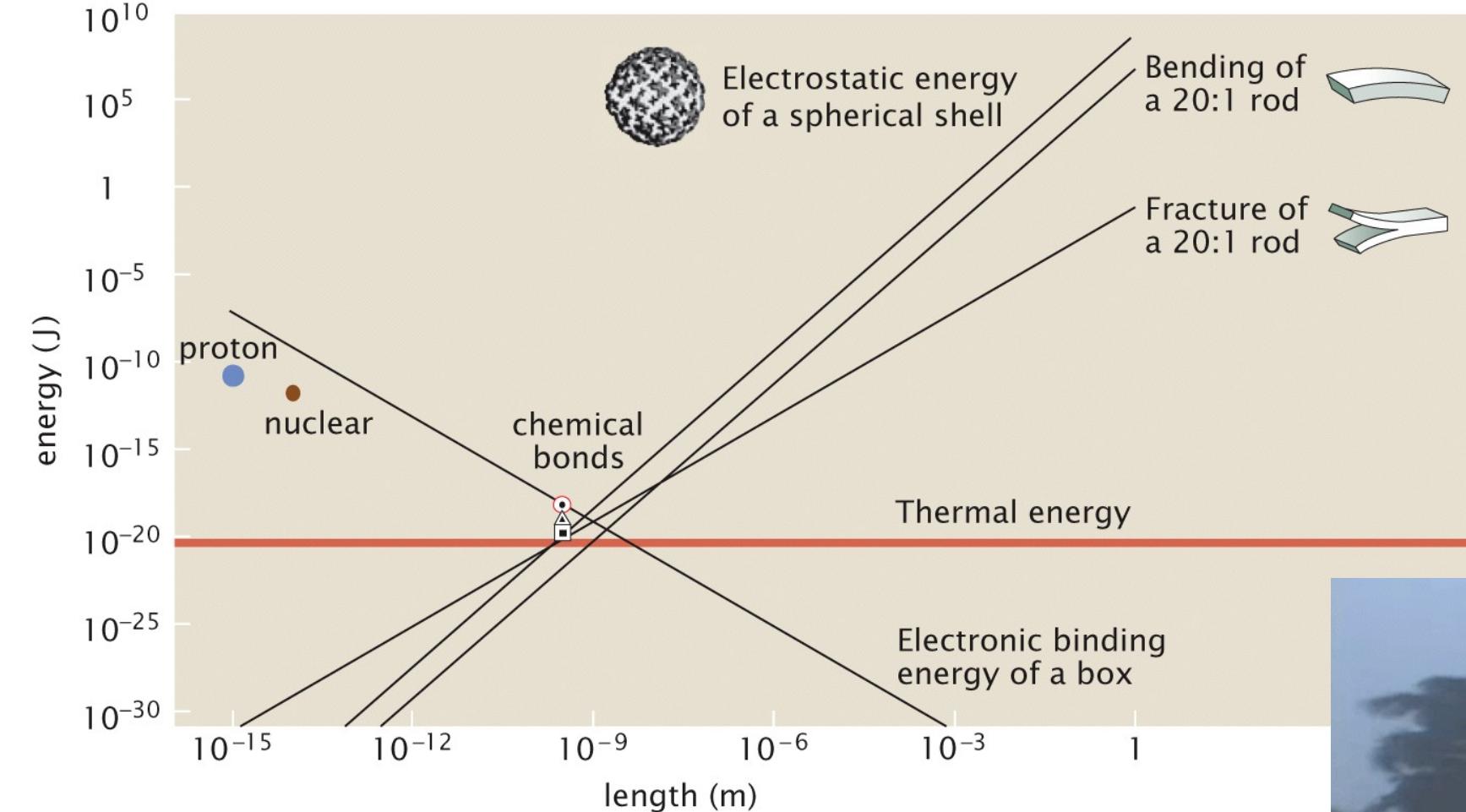


Figure 5.1 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Electrostatics, Mechanics, Thermal fluctuations :-  
All of these have a say in how a Nanoscale  
machine would function



# Such Biological Machines have guided us in making Nano-Machines

## Nobel Prize in Chemistry 2016 ... Design and Synthesis of Molecular Machines



1944



1942



1951

**Jean-Pierre Sauvage**

University of Strasbourg

**Sir James Fraser Stoddart**

Northwestern University,  
Evanston, IL, USA

**Bernard Lucas Feringa**

University of Groningen,  
Netherlands

A molecular-level machine can be defined as “*an assembly of a distinct number of molecular components that are designed to perform machinelike movements (output) as a result of an appropriate external stimulation (input)*”.<sup>1</sup> Furthermore, a machine requires a supply of energy for its operation, and can be driven by suitable energy sources.

Scientific Background on the Nobel Prize in Chemistry 2016

MOLECULAR MACHINES

Compiled by the Class for Chemistry of the Royal Swedish Academy of Sciences

## QUESTIONS/FURTHER READING

1. How does an Atomic Force Microscope (AFM) work ? What is it used for?
2. What is the meaning of Intramolecular FRET and Intermolecular FRET ? What is the magnitude of distances being measured in such FRET experiments?
3. Where are most TRP channel proteins found in the cell? Why is it difficult to study the structure of these proteins?
4. Check slide titled “The simplest Optical trap” :-
  - How do you make a simple Beam expander ?
  - What happens if you move the Biconvex Lenses L1 and L2 closer to each other?
5. What kind of problems do you anticipate in making an artificial Nanomachine? How does Nature solve this problem ?