

Computer Modeling:

The Lab in your Laptop

November 30th, 2008

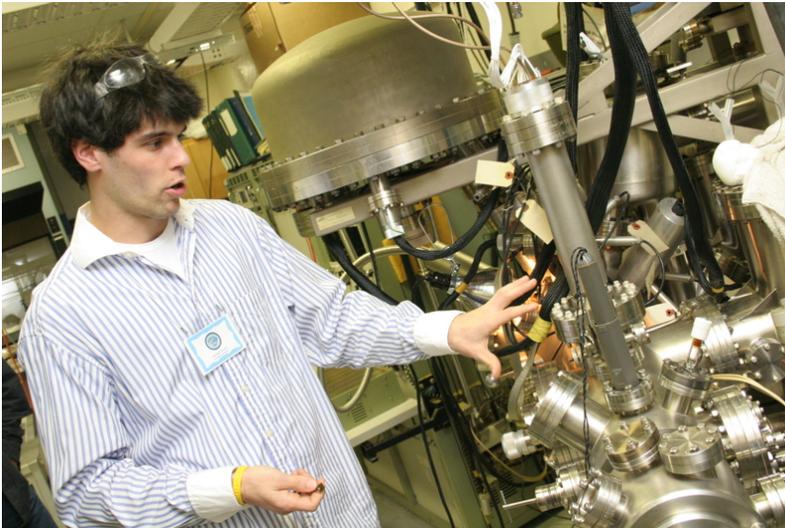
Scientists at work

“An **experiment** is a question which science poses to Nature, and a **measurement** is the recording of Nature's answer.”

- *Max Planck*

(Scientific Autobiography and other papers, 1949)

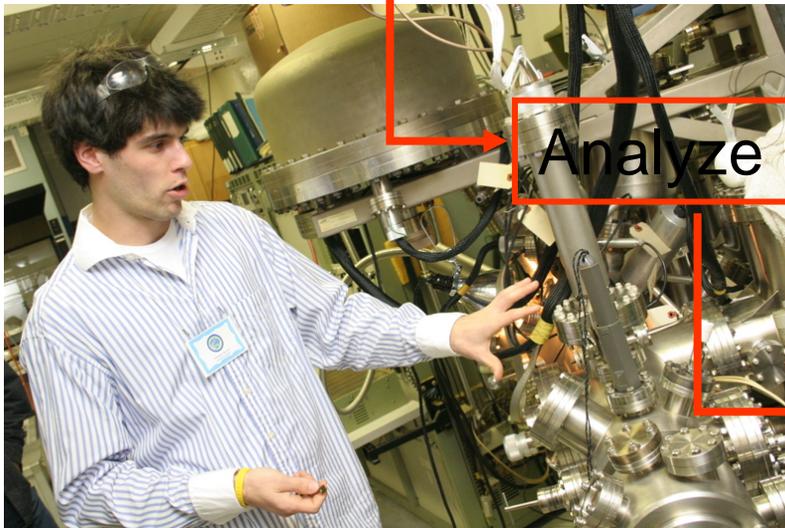
Scientists at work



In the lab

In the field

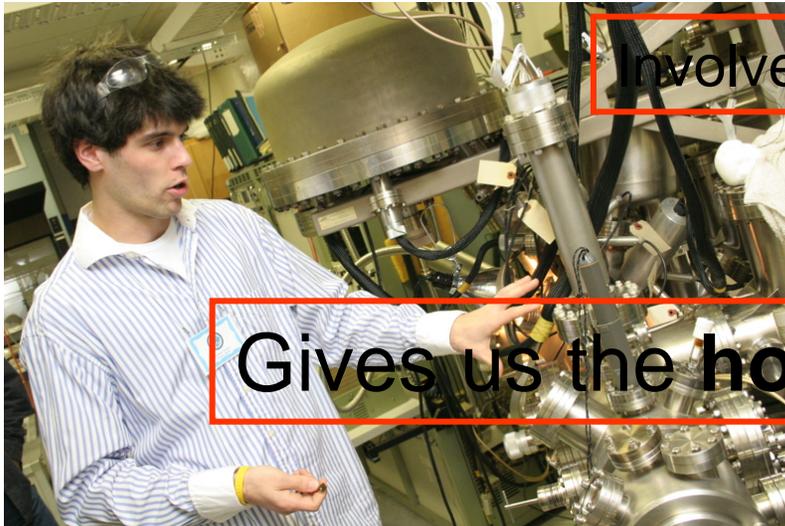
Scientists at work



In the lab

In the field

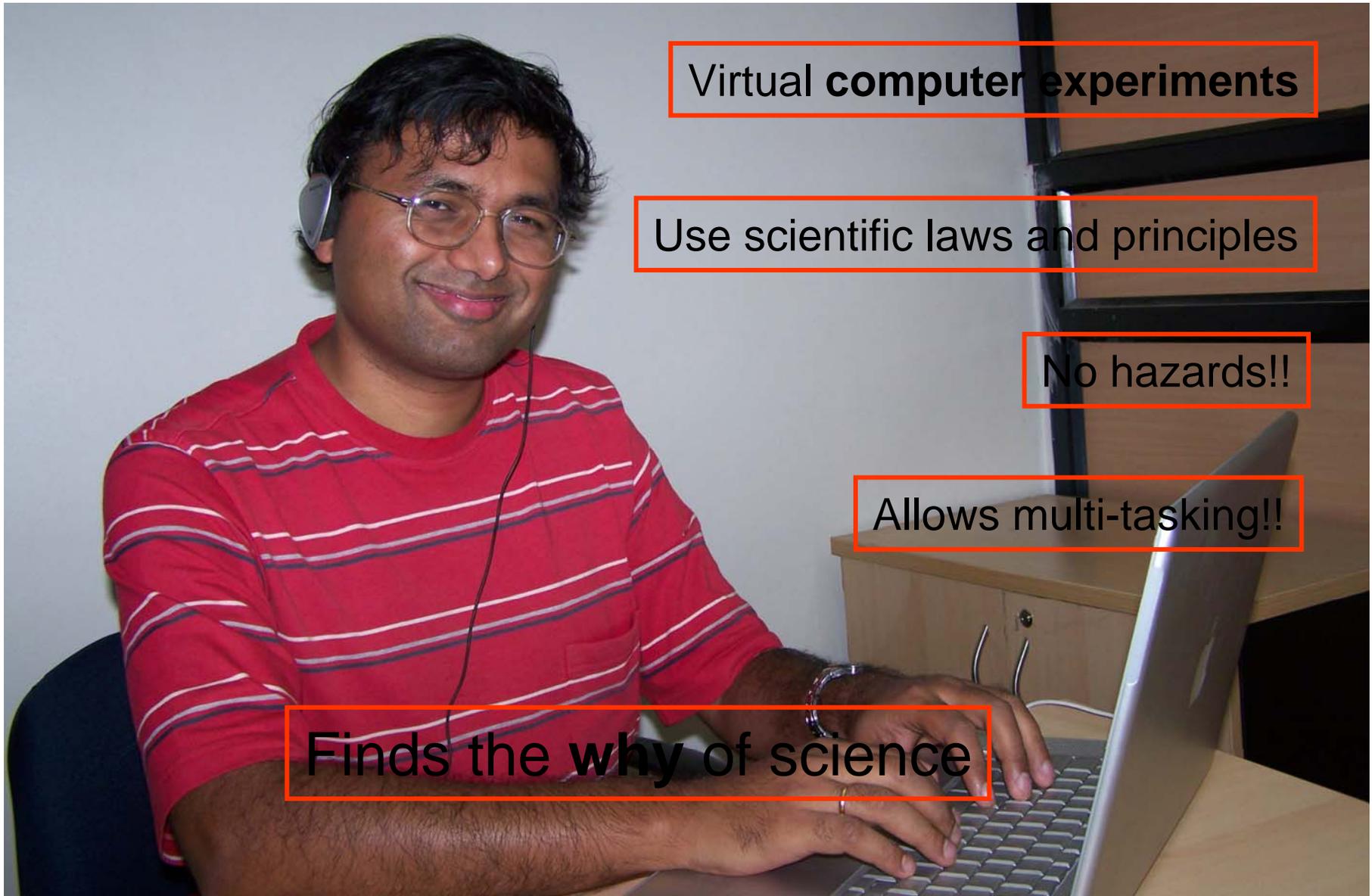
Scientists at work



In the lab

In the field

The Computational Scientist



Virtual computer experiments

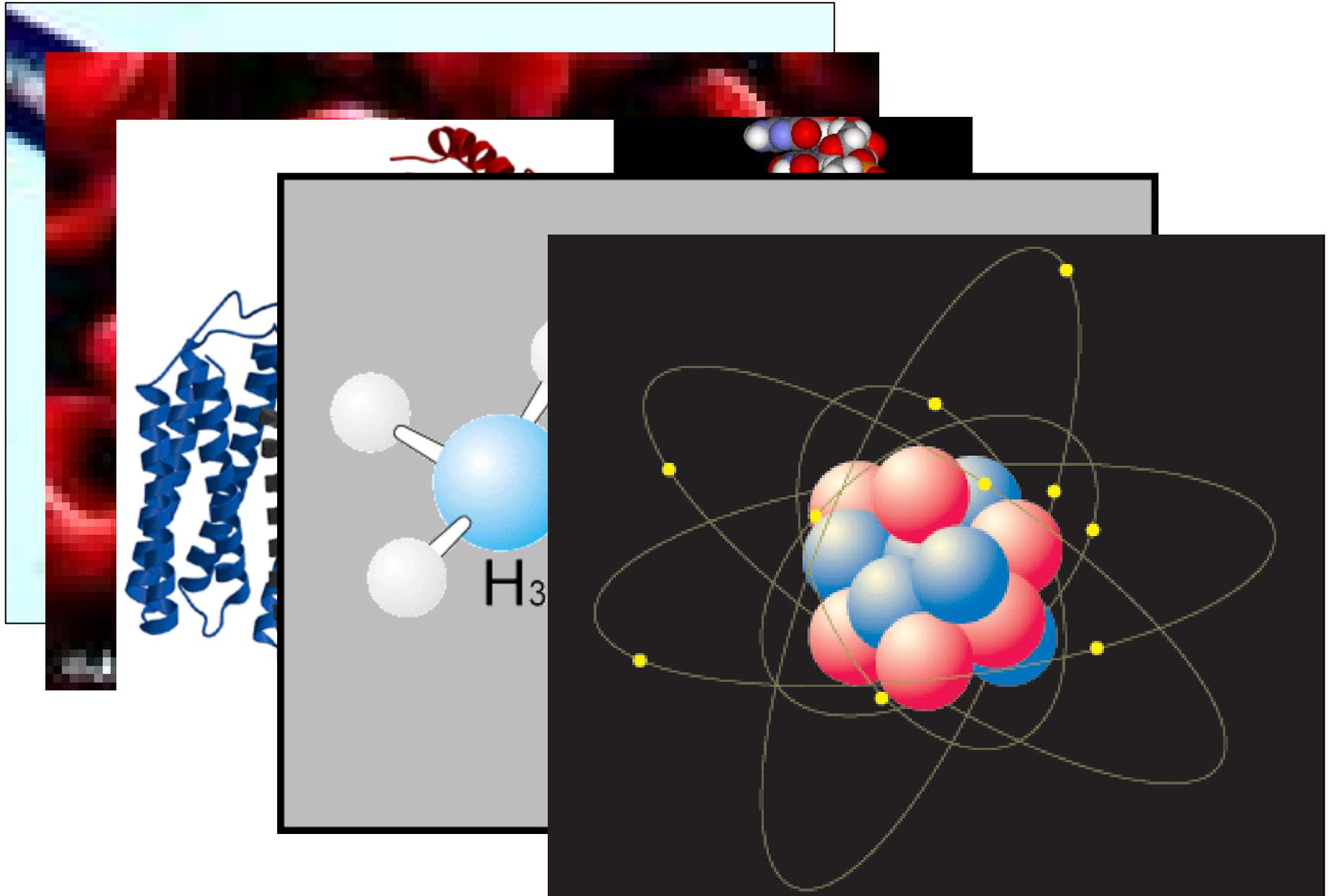
Use scientific laws and principles

No hazards!!

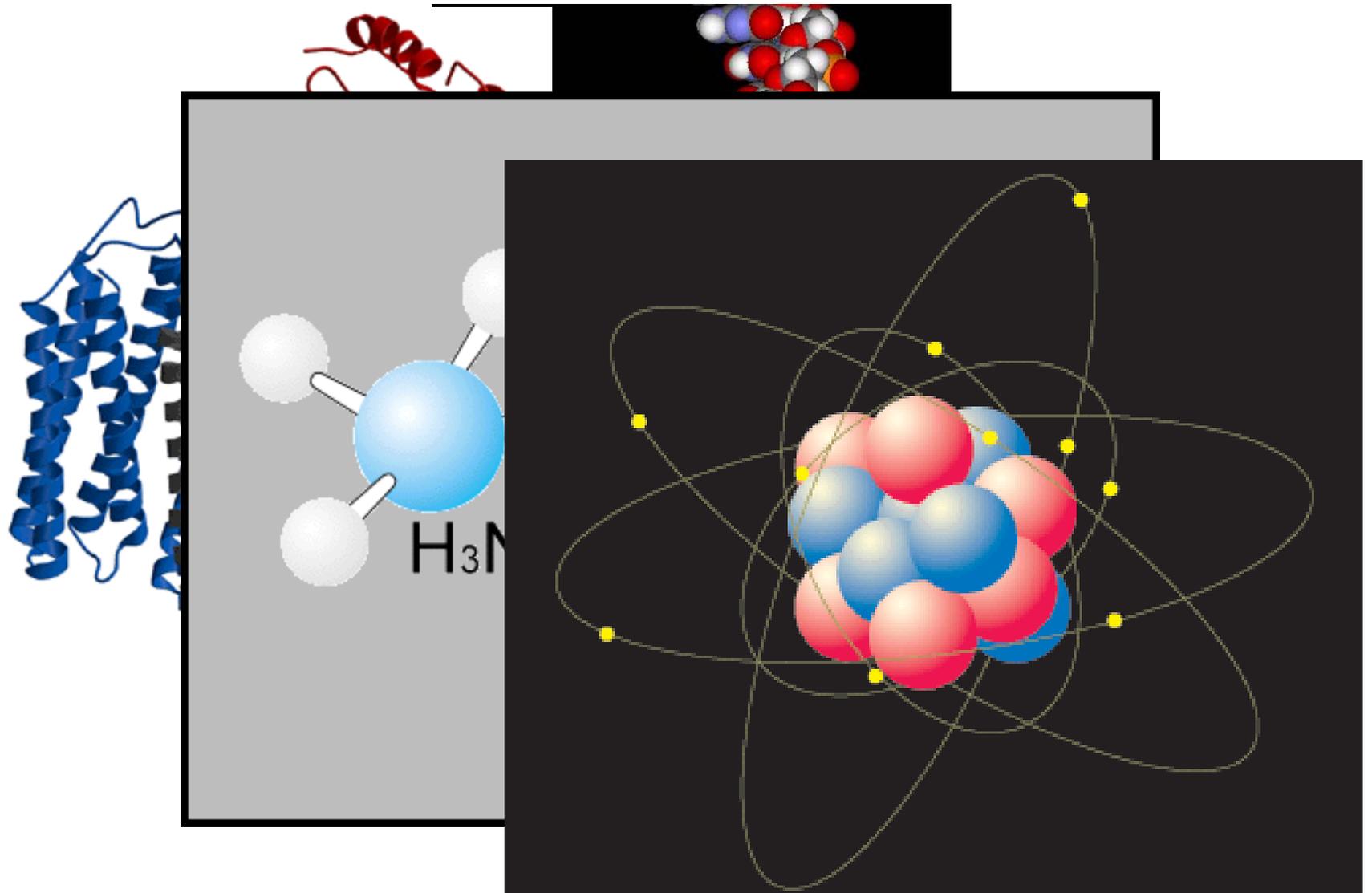
Allows multi-tasking!!

Finds the **why** of science

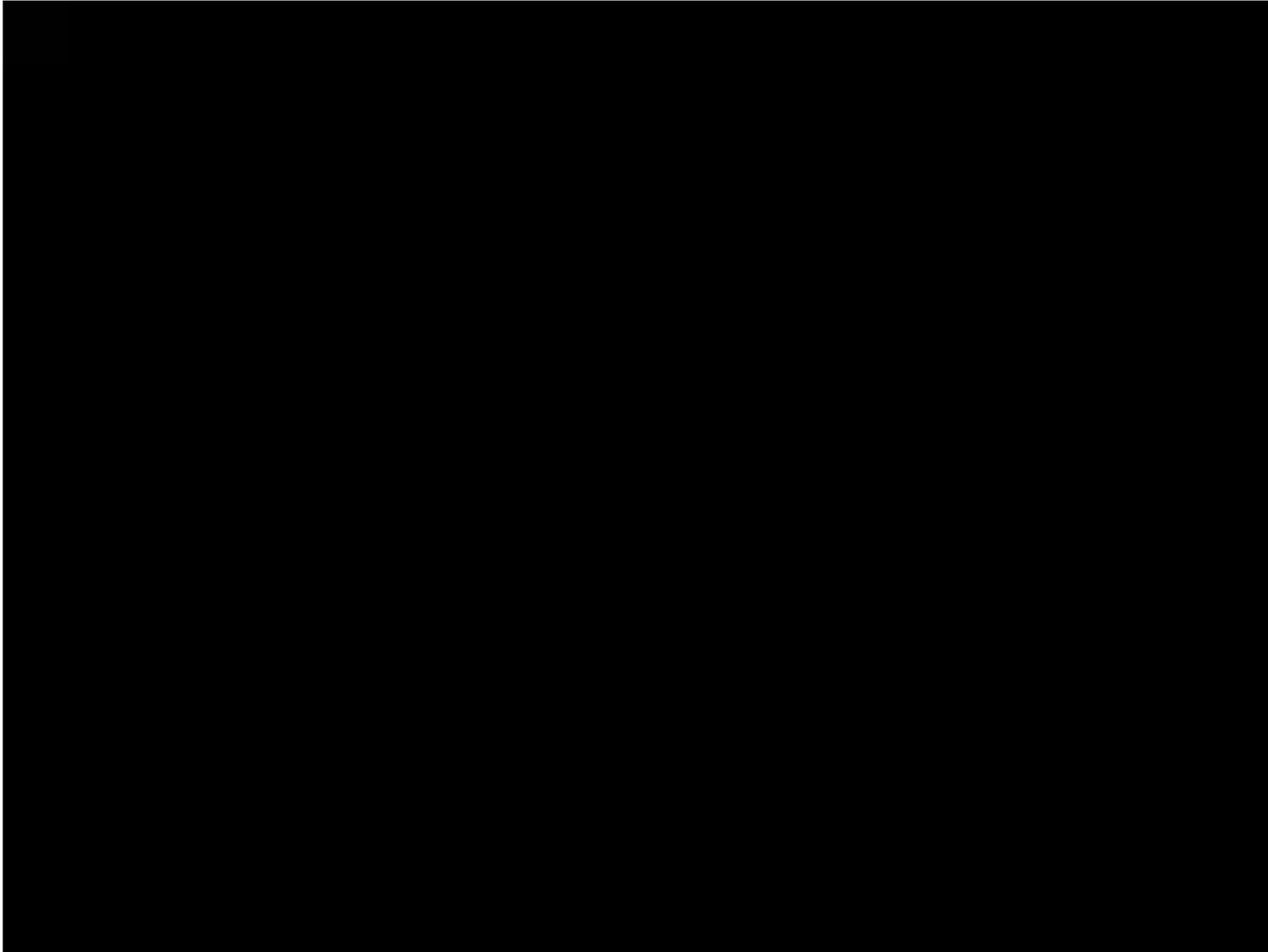
Sizes of things in nature



Sizes of things in nature

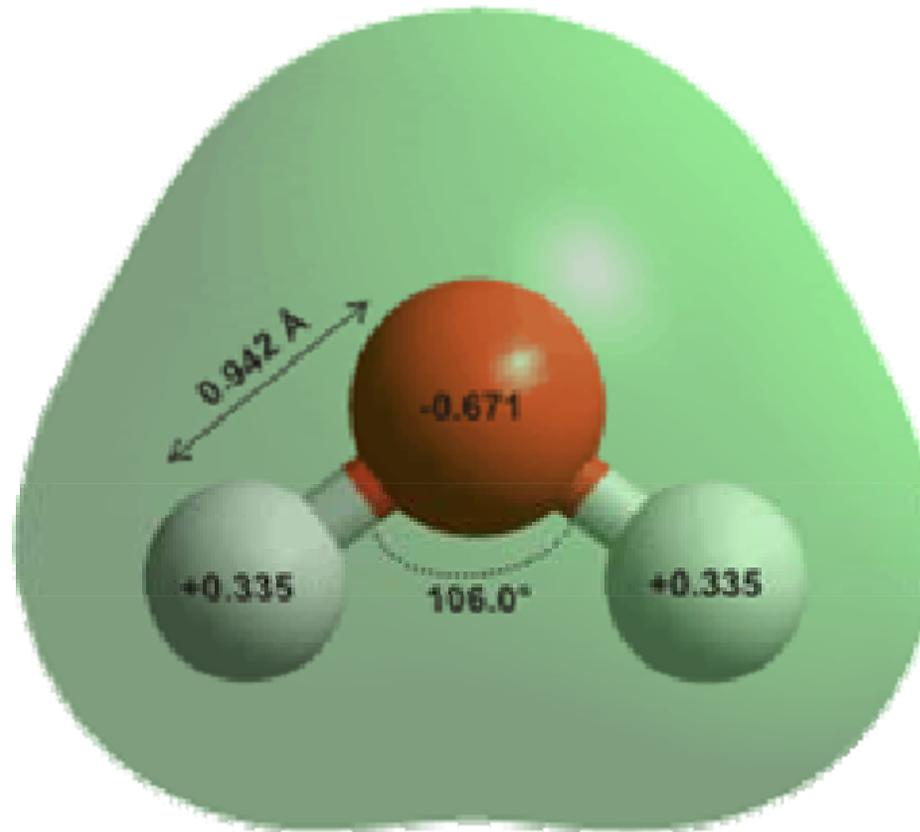


Looking “inside” a cell



Biological molecules

1. Water

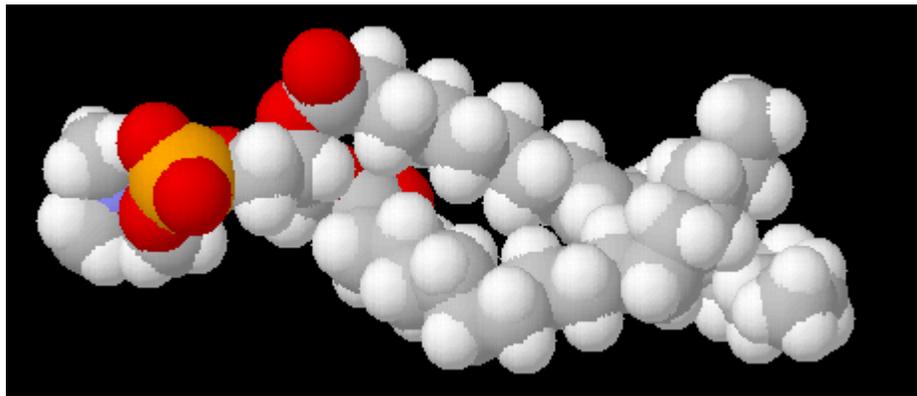


$1 \text{ \AA} = (1/10,000,000,000) \text{ metre}$

Biological molecules

2. Fatty molecules (Lipids)

Head
Hydrophilic (water loving)



Tail
Hydrophobic (water hating)

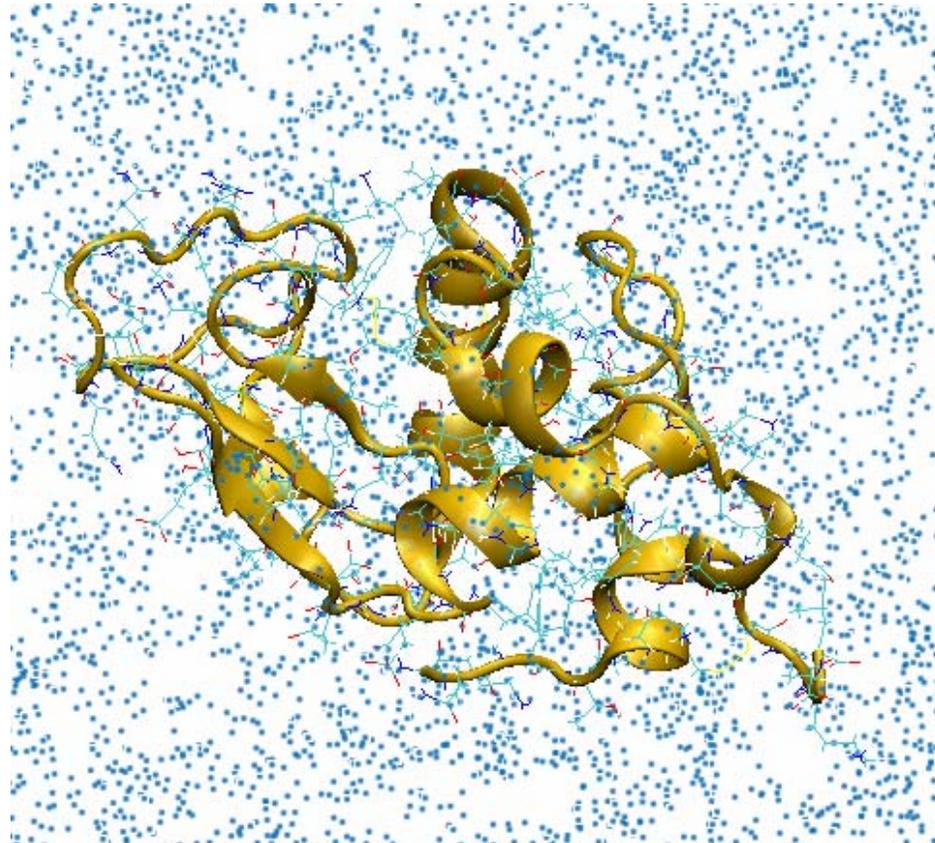
Biological molecules

3. Proteins



Biological molecules

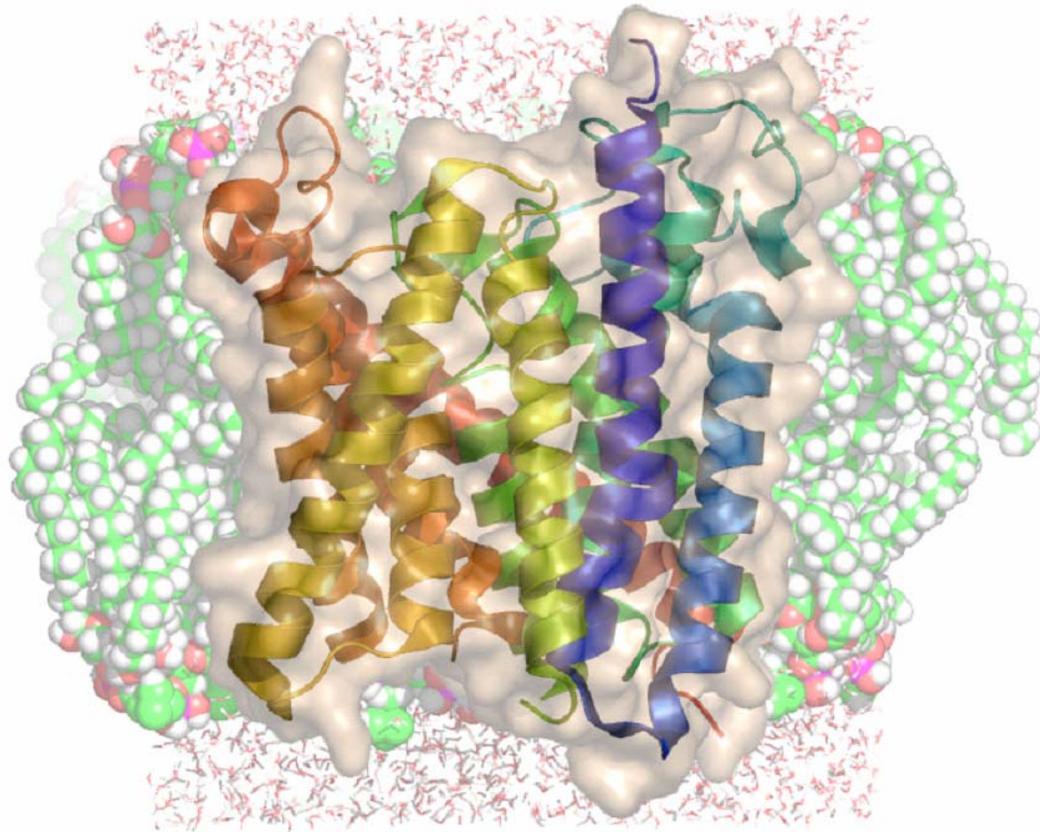
3. Proteins



Globular form
(surrounded by water)

Biological molecules

3. Proteins

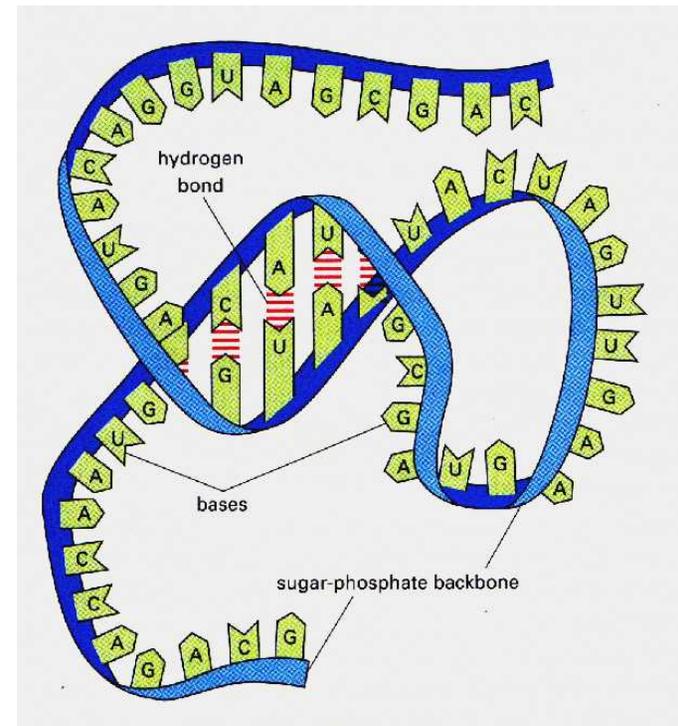
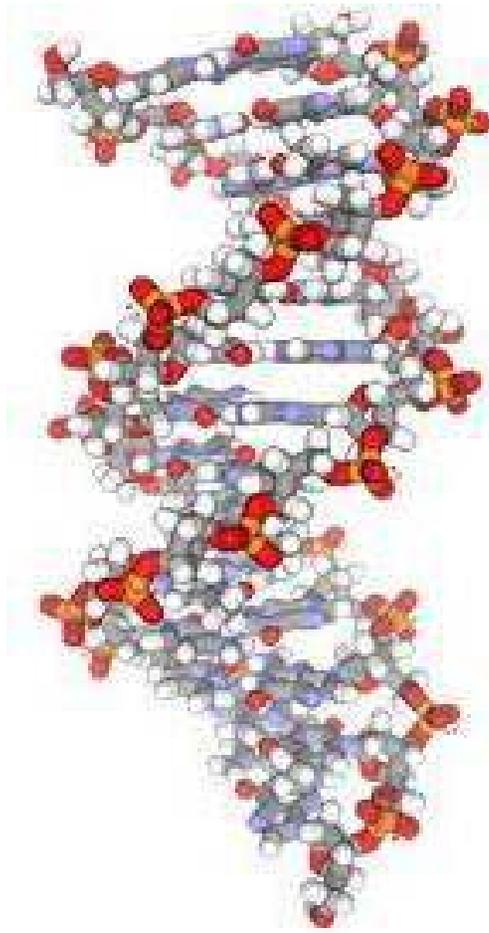


Inside cell membrane
(surrounded by lipids)

Biological molecules

4. Nucleic Acids

DNA

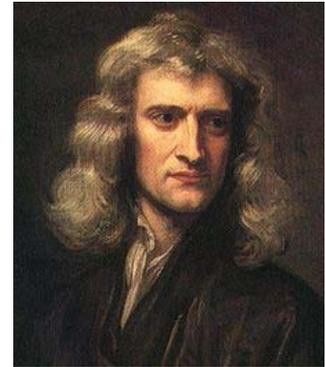


RNA

Principles behind computational biology

1. The Laws of Motion

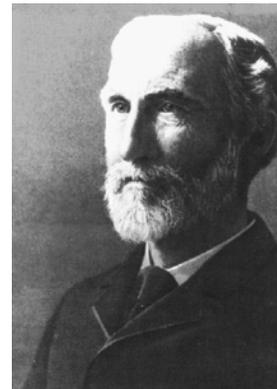
$$F = ma$$



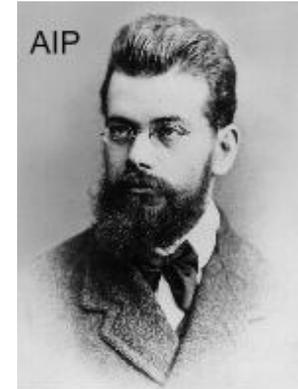
Isaac Newton

2. Statistical Mechanics

How to get **observables** from positions and speeds of atoms.



Gibbs



Boltzmann

3. The Energy-Minimum Principle

When an event occurs **spontaneously**, the total energy of the system always **decreases**.

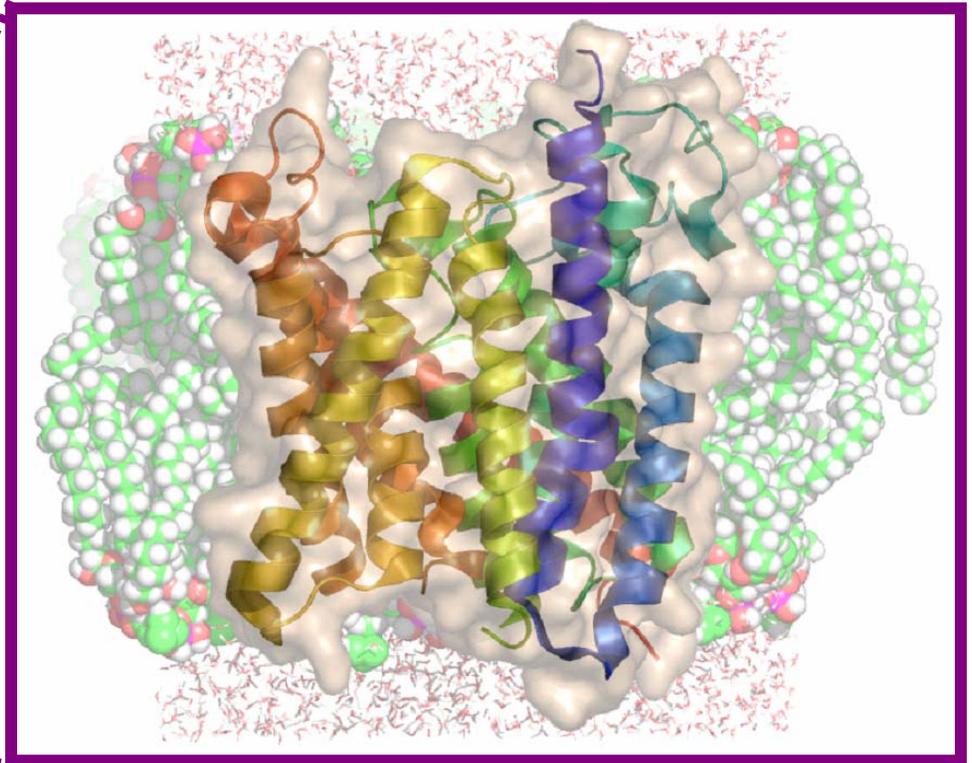
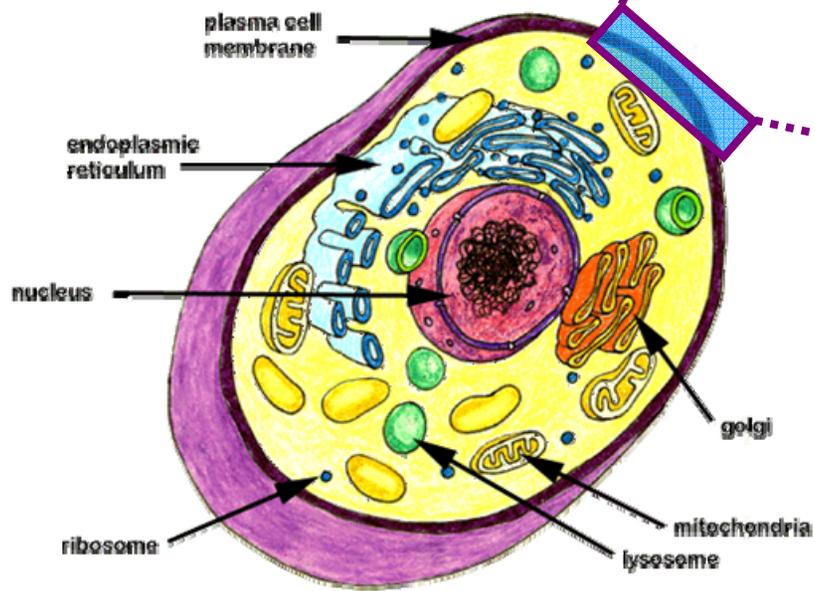
Initial positions
and speeds

Force between
atoms

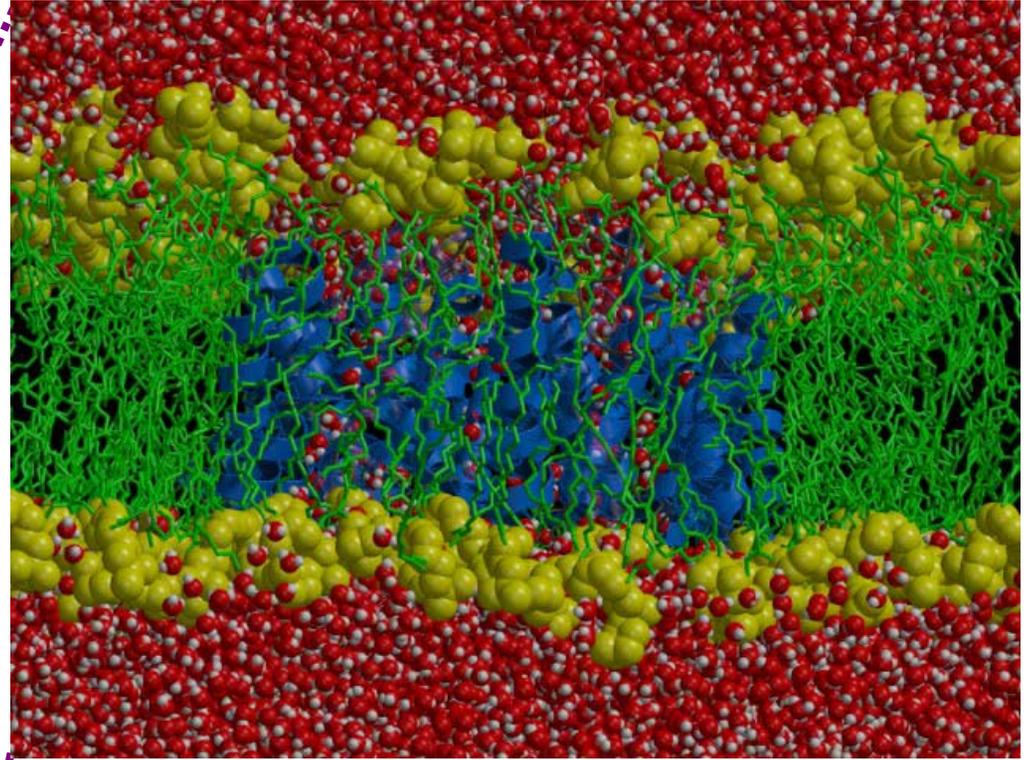
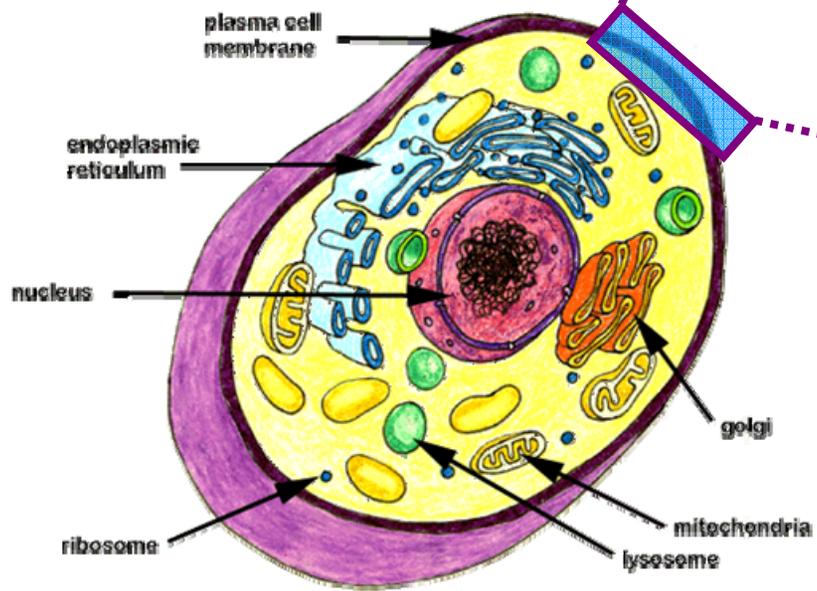


- Positions and speeds at every time point (*trajectory*)
- Calculate *observables*

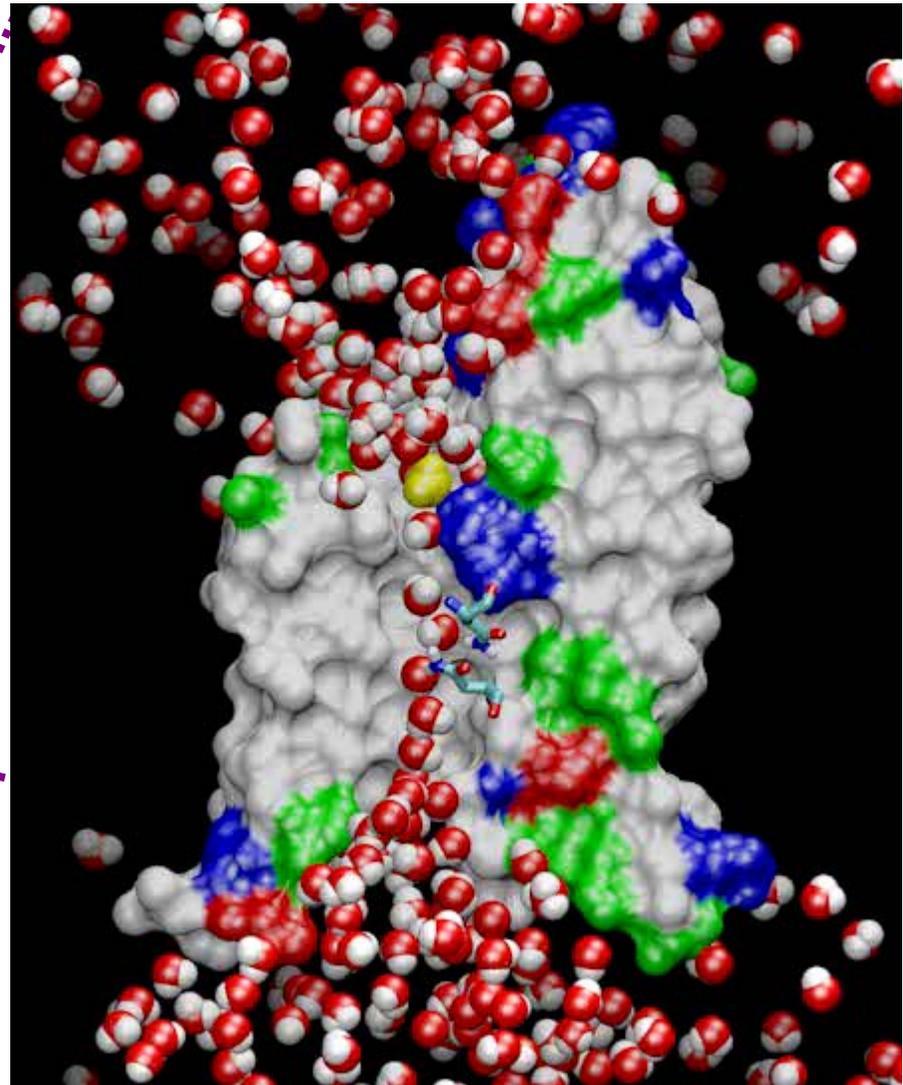
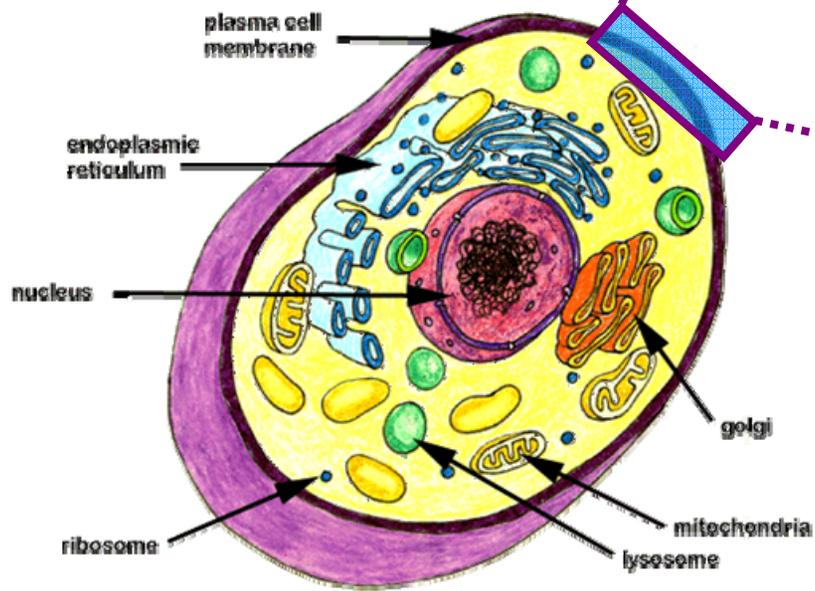
1. How do cells work?



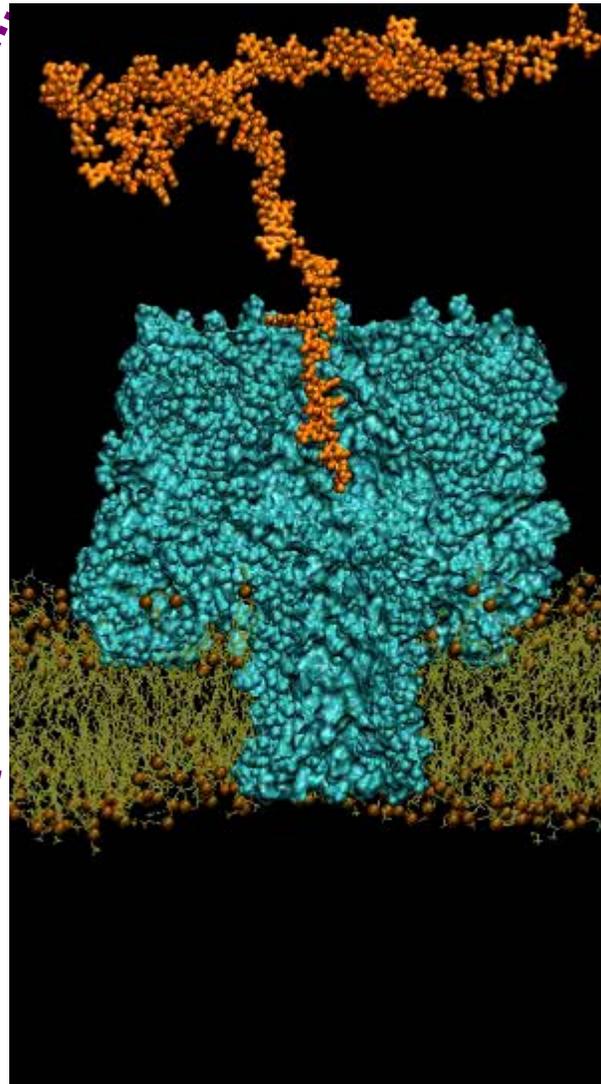
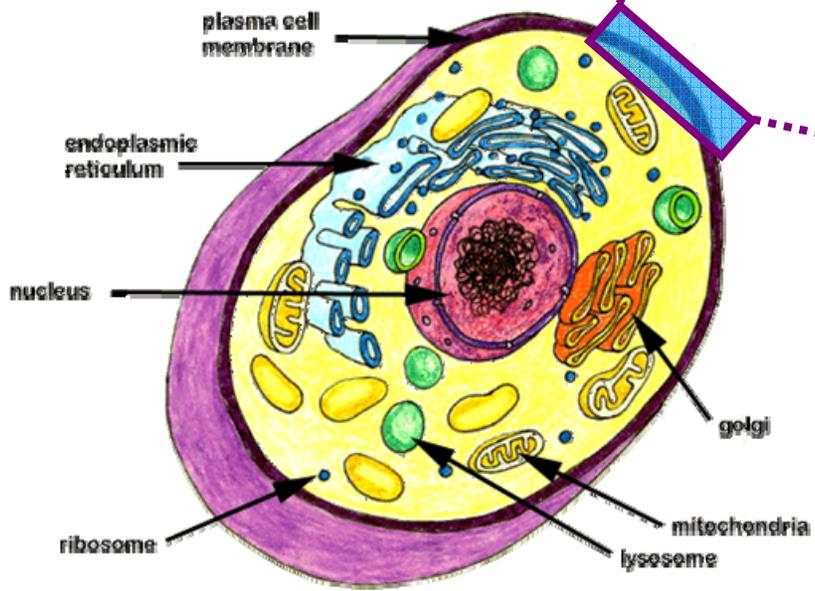
1. How do cells work?



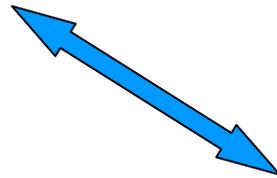
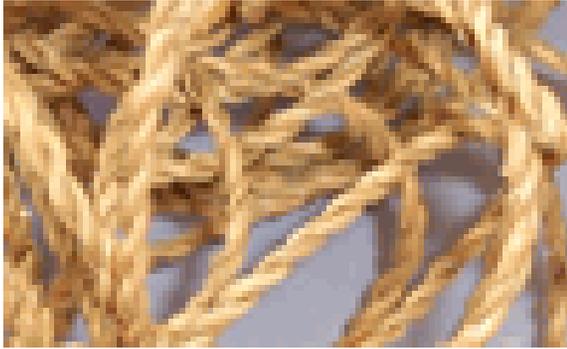
1. How do cells work?



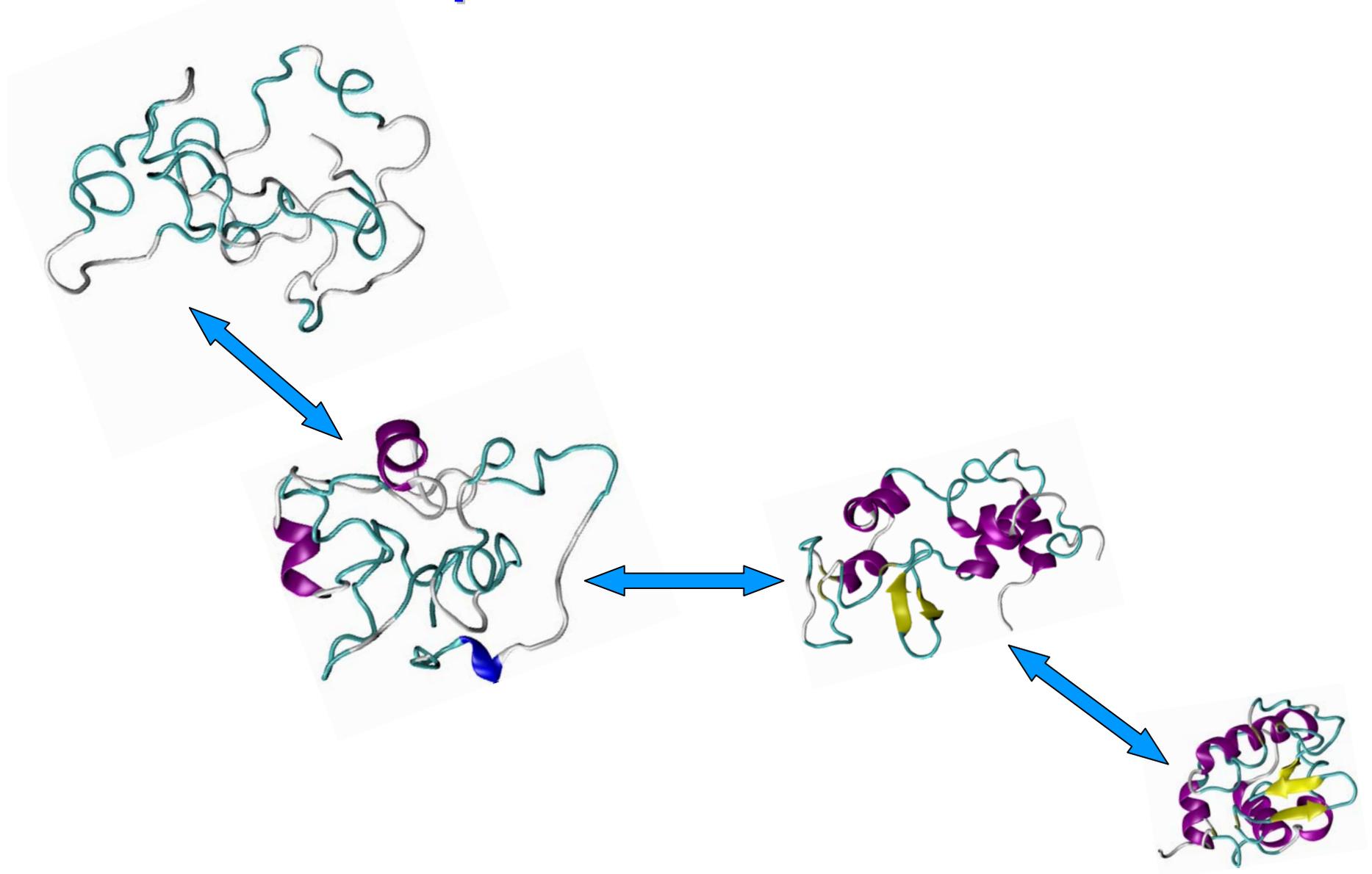
1. How do cells work?

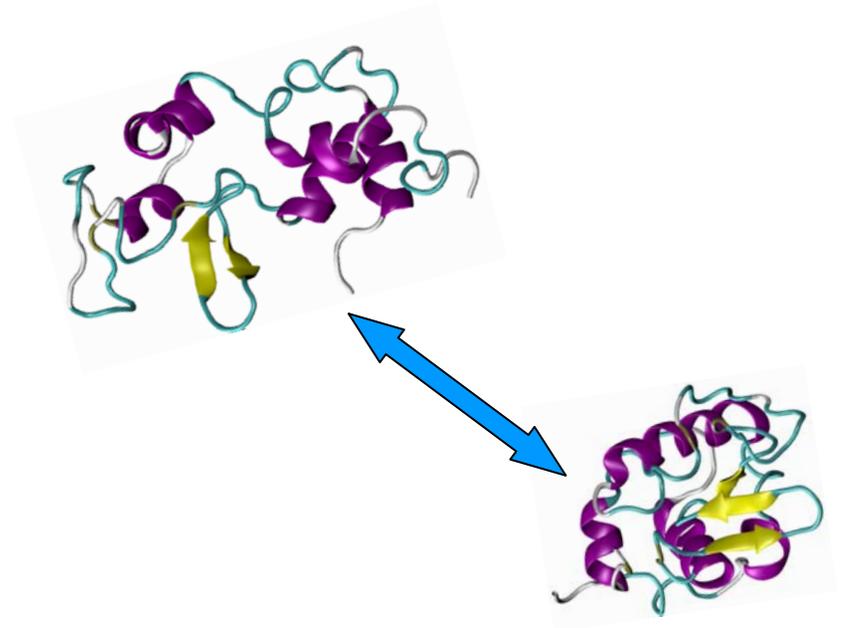


2. How does a protein “fold” inside a cell?



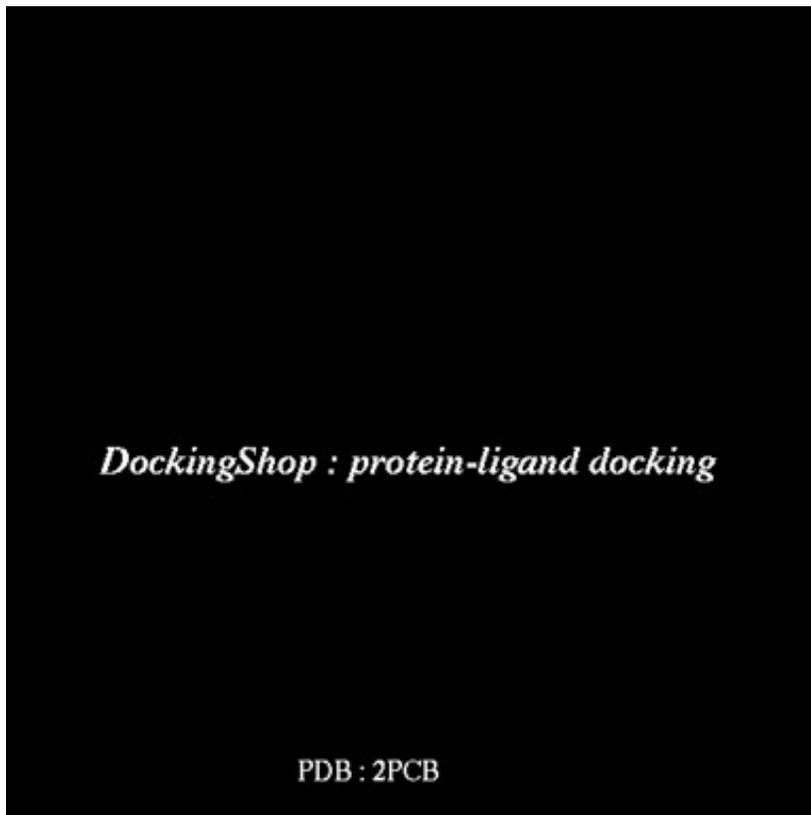
2. How does a protein “fold” inside a cell?





3. How do medicines (drugs) work?

- Certain proteins, called **enzymes** (eg. insulin), control biological function
- Some **molecules** can **bind to enzymes** and **change** how they behave

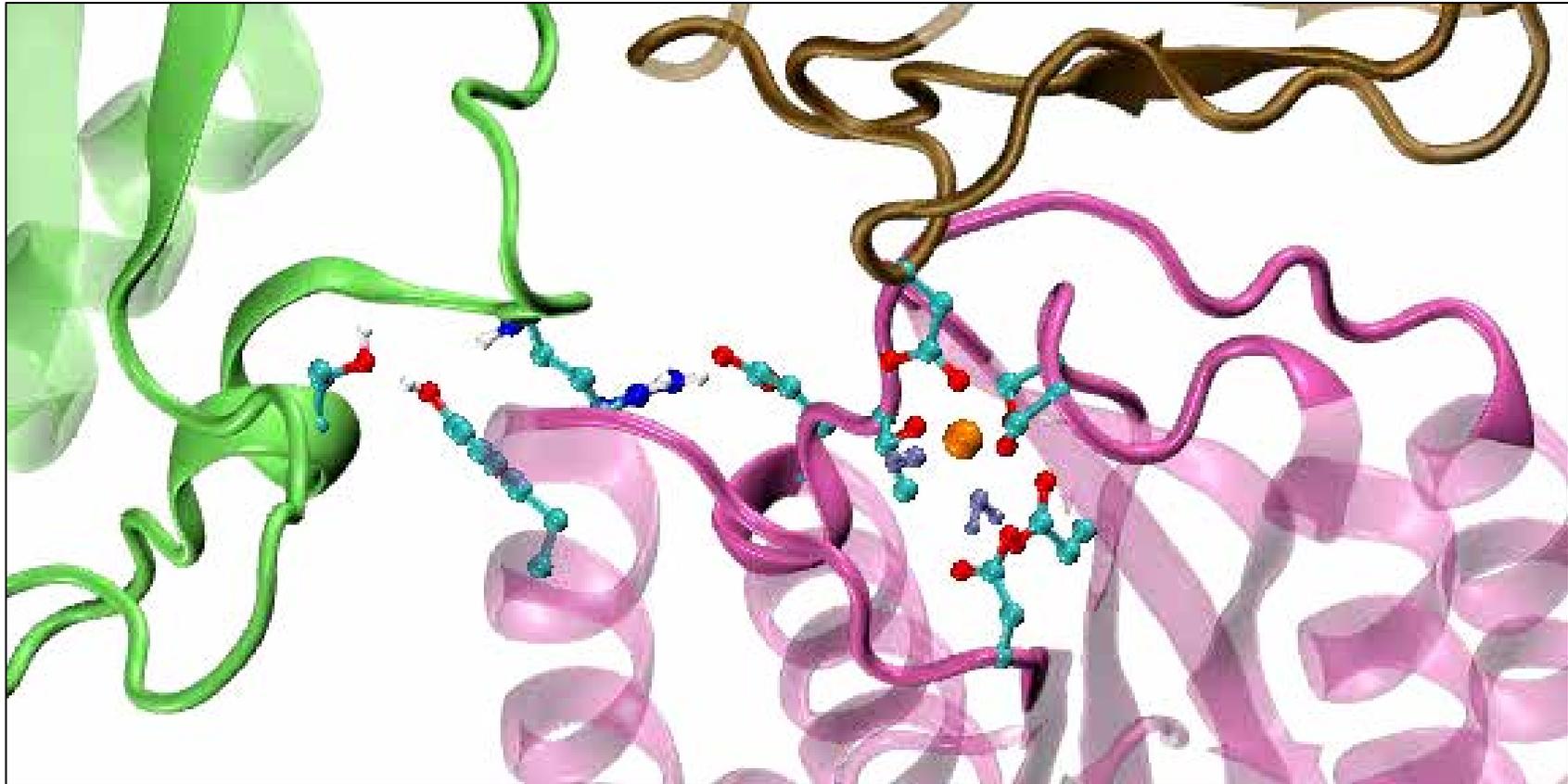


Find how energy changes on binding

Find effect of protein's shape on binding

Find drugs that bind more strongly or weakly to enzyme

The “lab” on a finer scale:



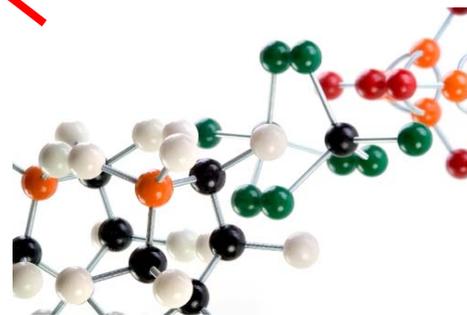
From the Small to the Very Small



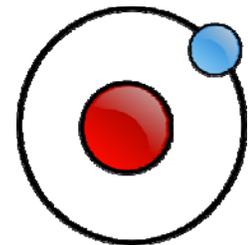
Atoms and Molecules: Building Blocks of Everything



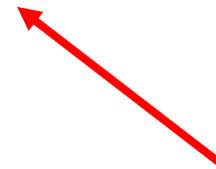
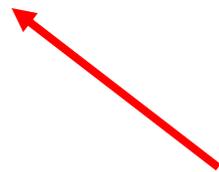
Plastic Cup Holder

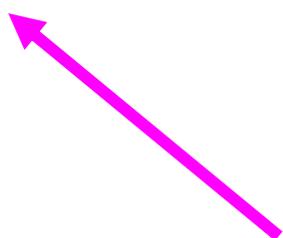
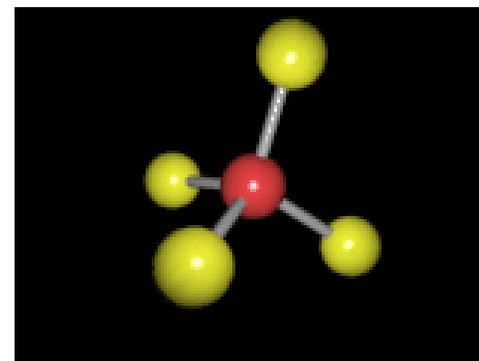
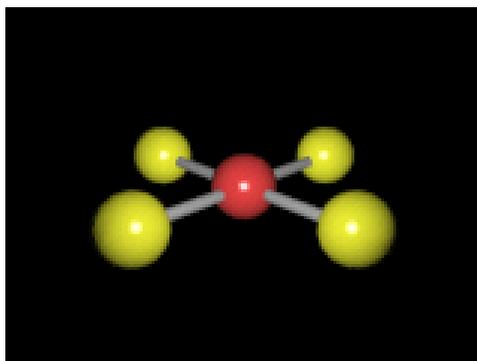
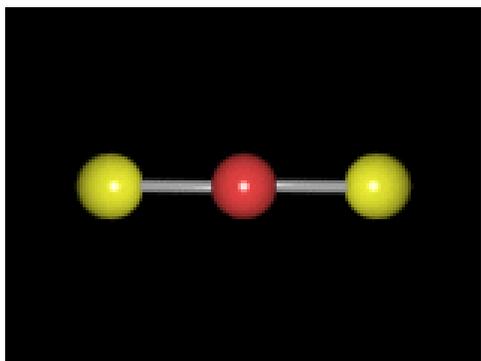


Molecule

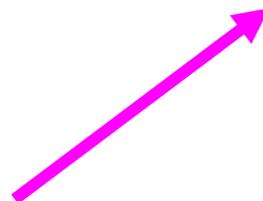
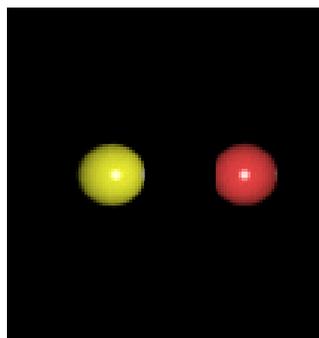
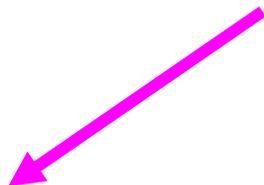


Atom

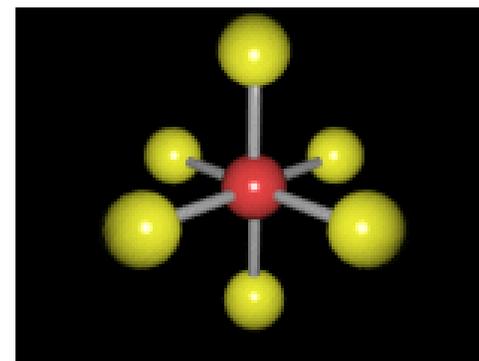
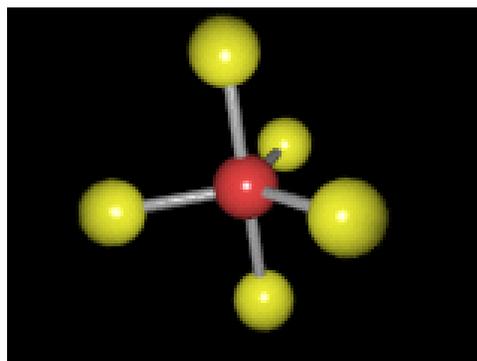
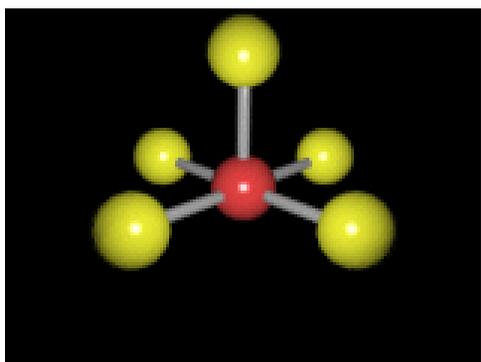
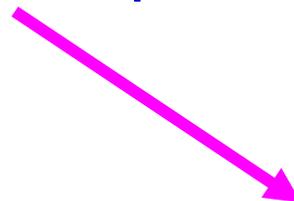


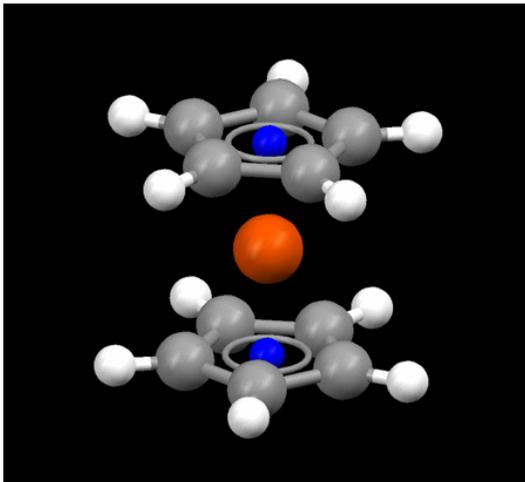
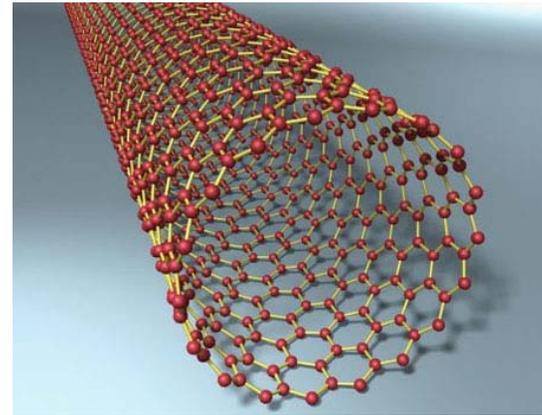
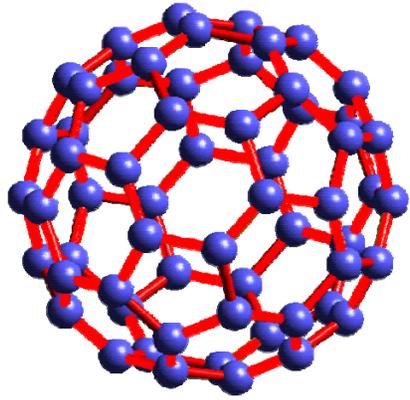


Molecular



Shapes







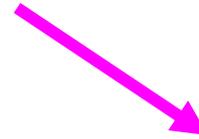
So why are shape and structure so important?

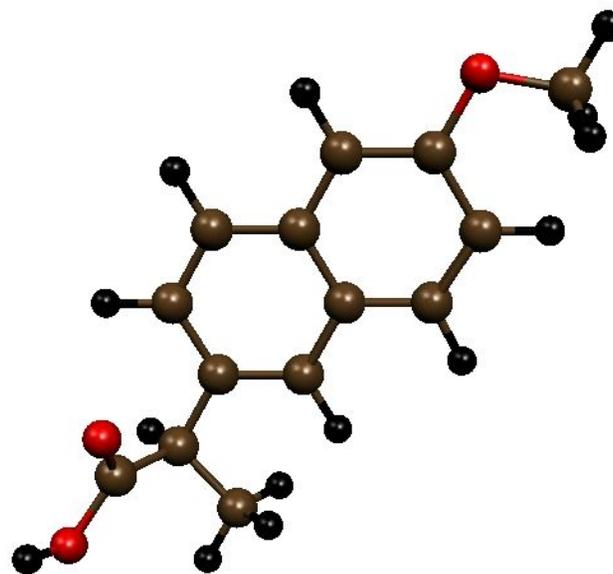
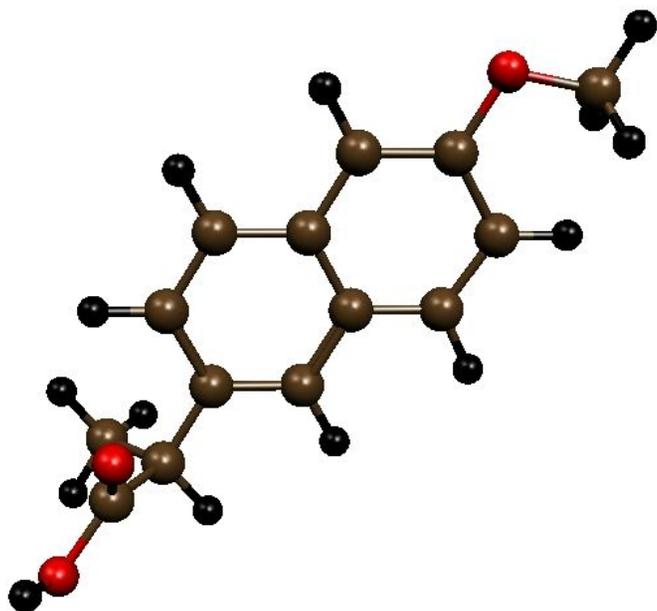


Shitake Mushrooms



Angel of Death Mushrooms

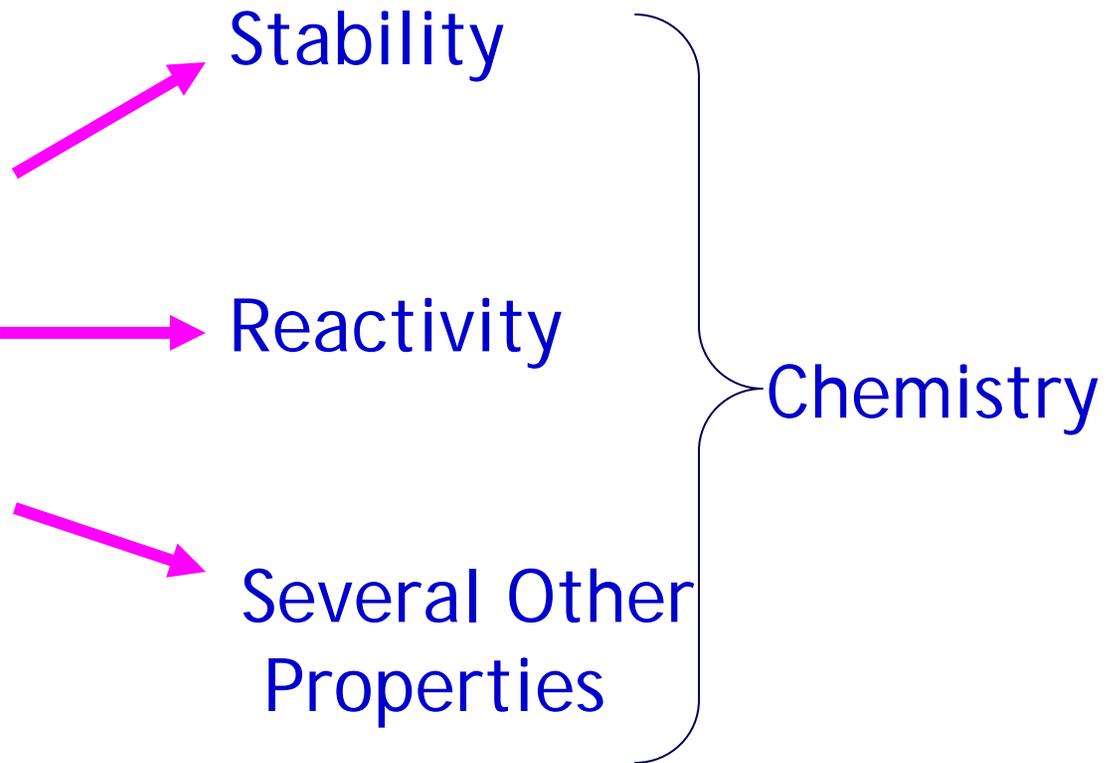




Medicine



Poison



Experimental Methods can Determine Structure



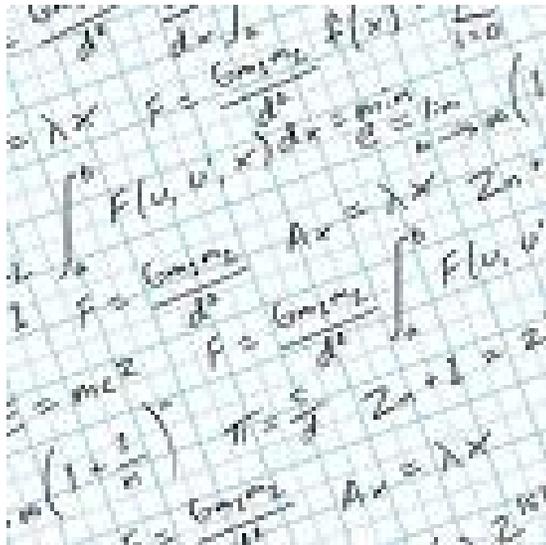
NMR Apparatus



X-Ray Diffractometer



Using Theory and Computers





How can we do that?
What kind of Math
do we need to know?

Just play dice!





“God Does Not Play Dice!”

Albert Einstein

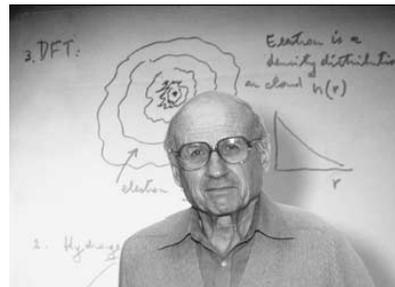
Giants of Theoretical Physics /Chemistry



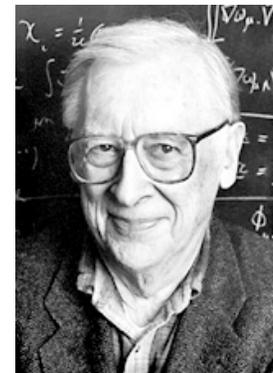
Max Planck



Erwin Schrodinger

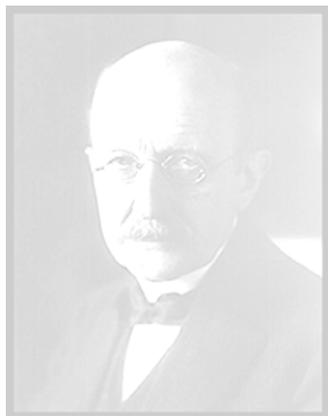


Walter Kohn



John Pople

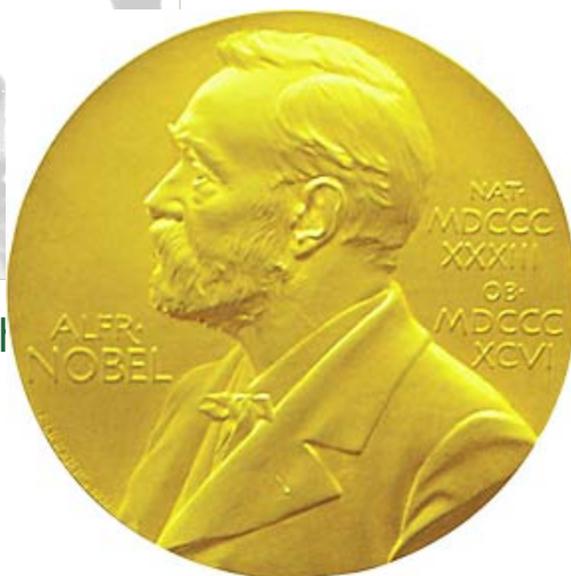
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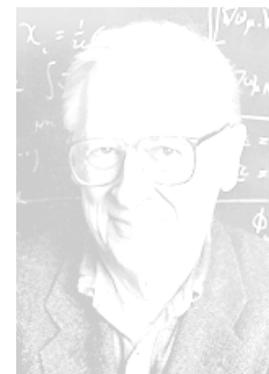
Max Planck



Erwin Schrödinger

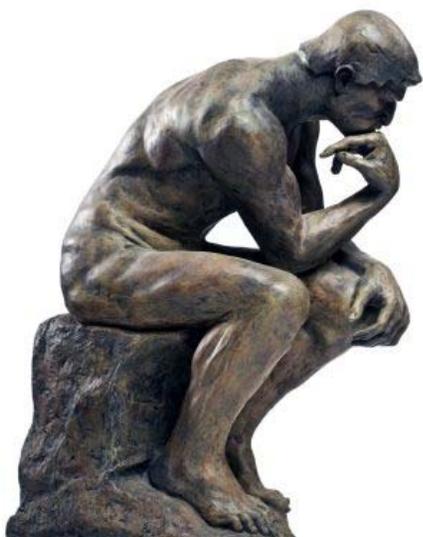


Walter Kohn

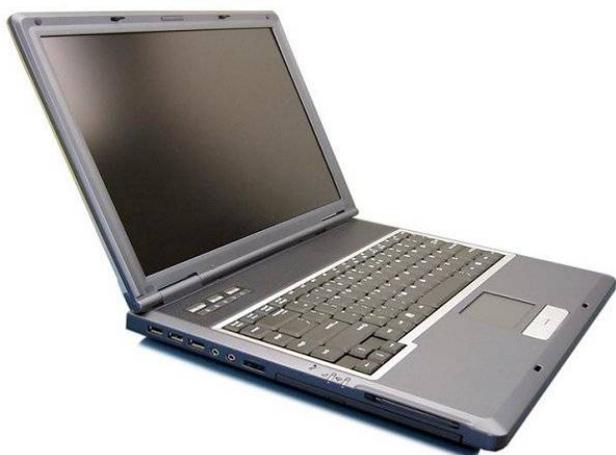


John Pople

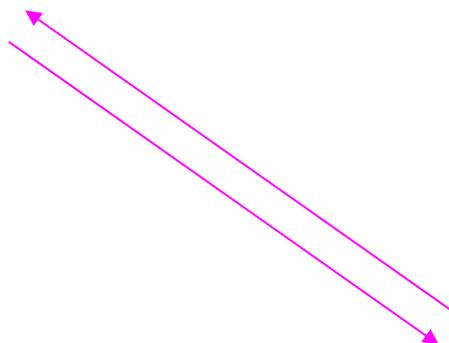
Current Work in Theoretical Chemistry



Developers



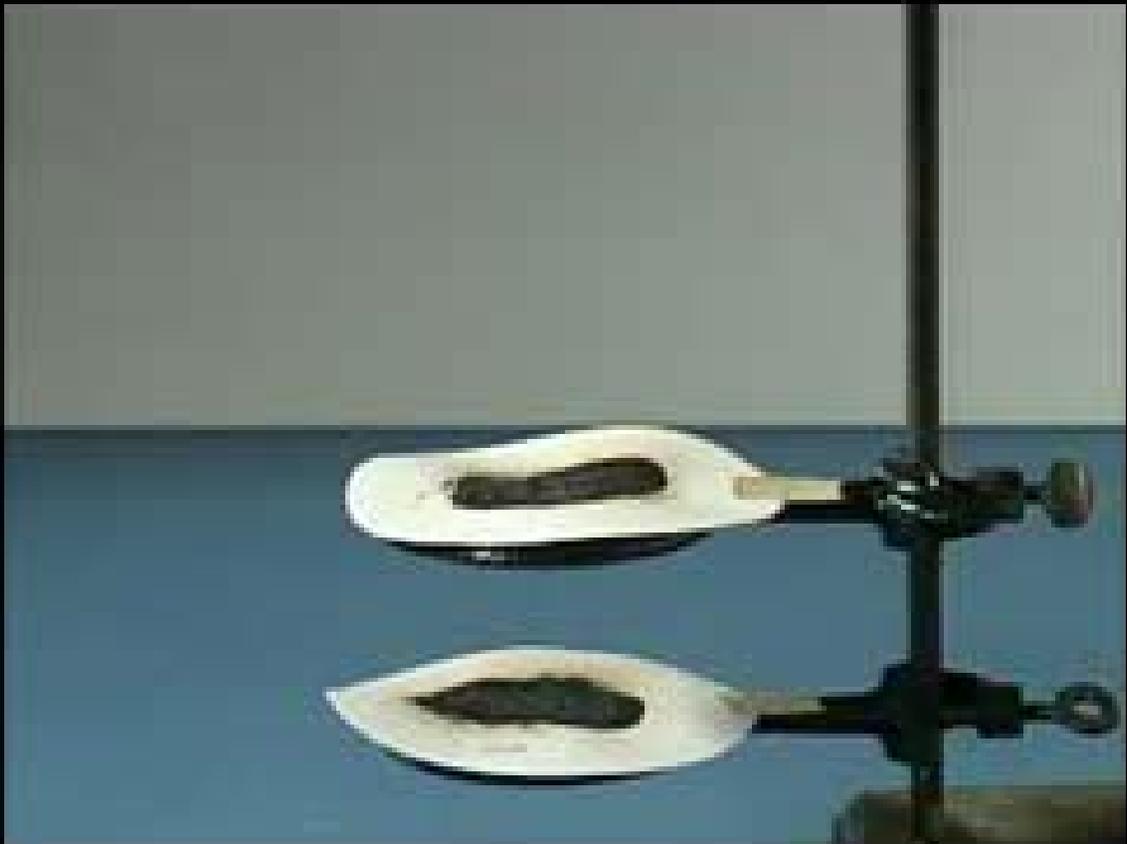
Appliers





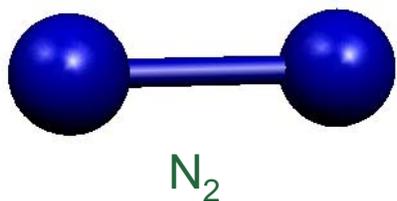
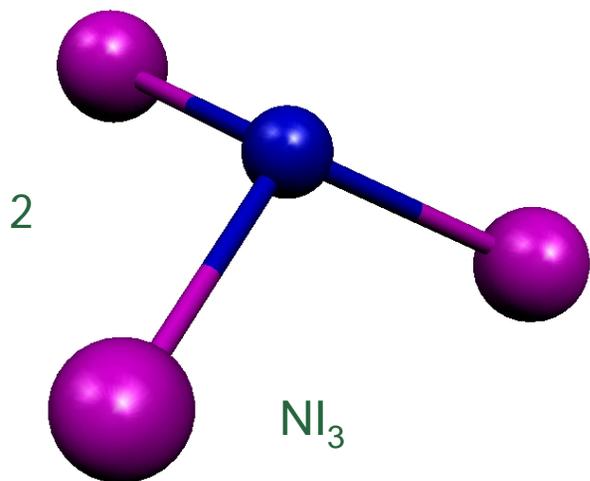
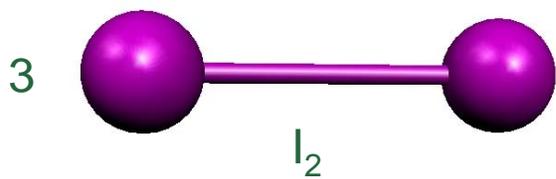
: “Undistorts” a Molecule

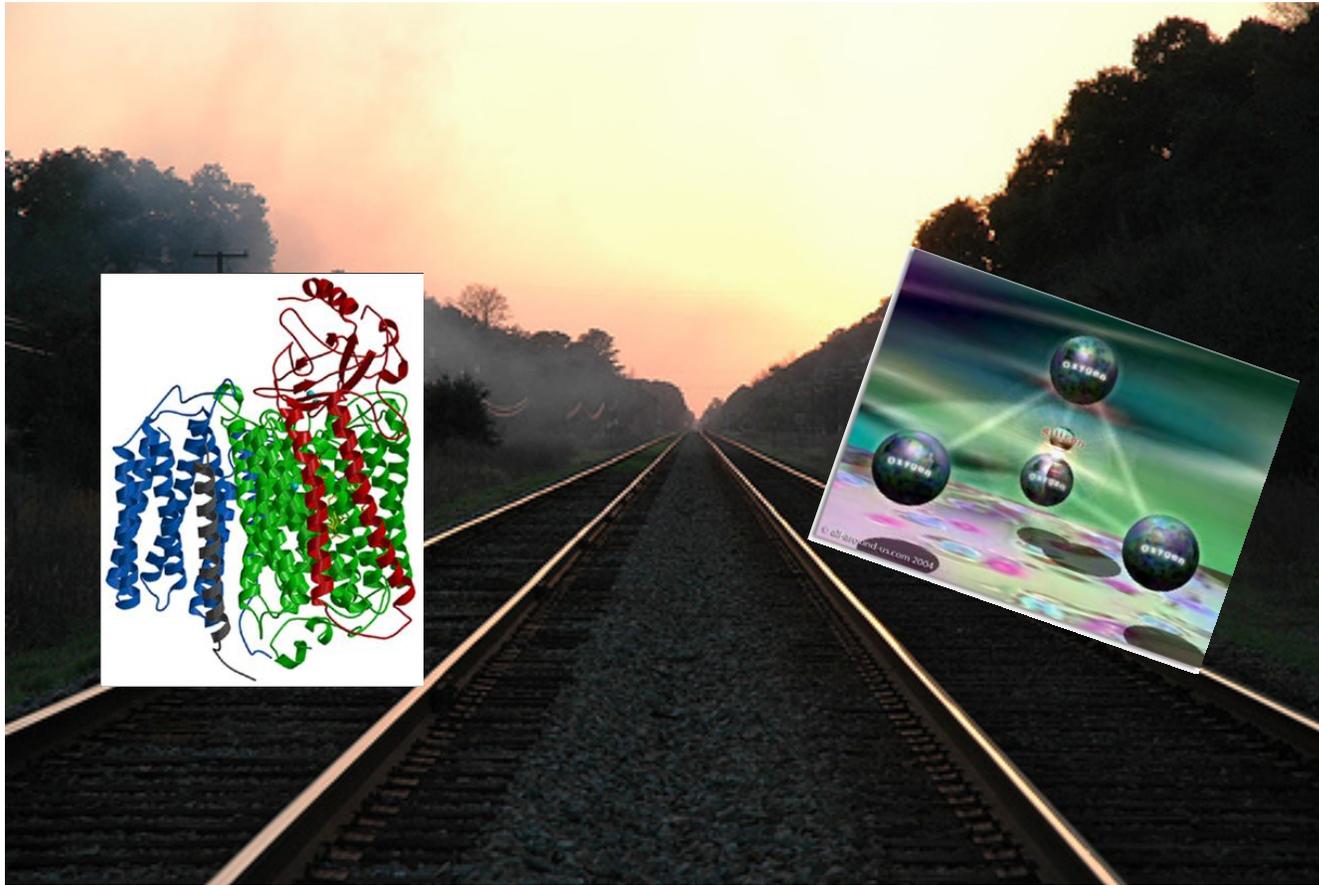






: Follows a Reaction





Acknowledgements:

- *Protein movies* from <http://www.ks.uiuc.edu/~kschulte/>
(Theoretical & Computational Biophysics Group,
Univ. Illinois at Urbana-Champaign)
- *Cell animation* from <http://multimedia.mcb.harvard.edu/>
(BioVisions, Harvard University)

THANK YOU

