The Micro- Macro- Motorheads

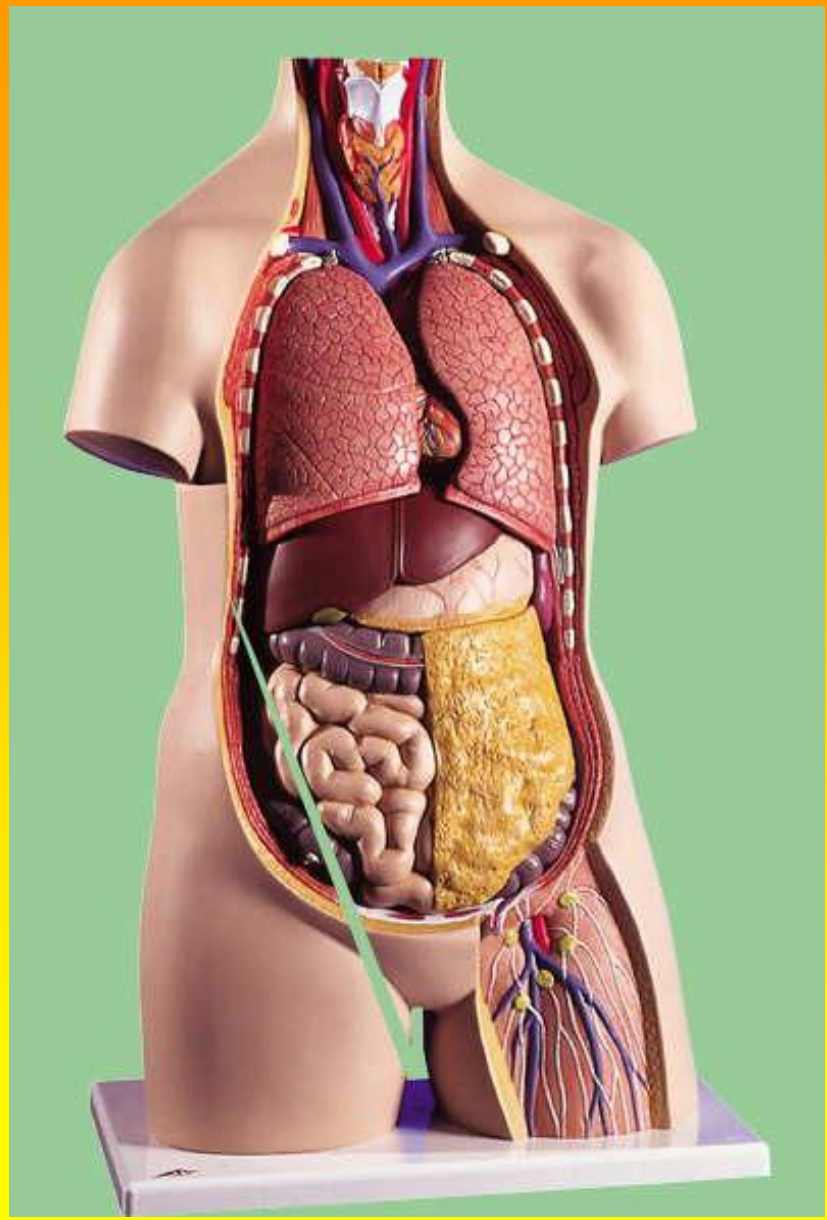
Proudly present...

Function and Application of Biomolecular Motors

- Most of the action inside YOUR body occurs at the Nanoscale Level

- While YOU are listening 10,000 different Nanomachines are at work!

  e.g. Enzymes



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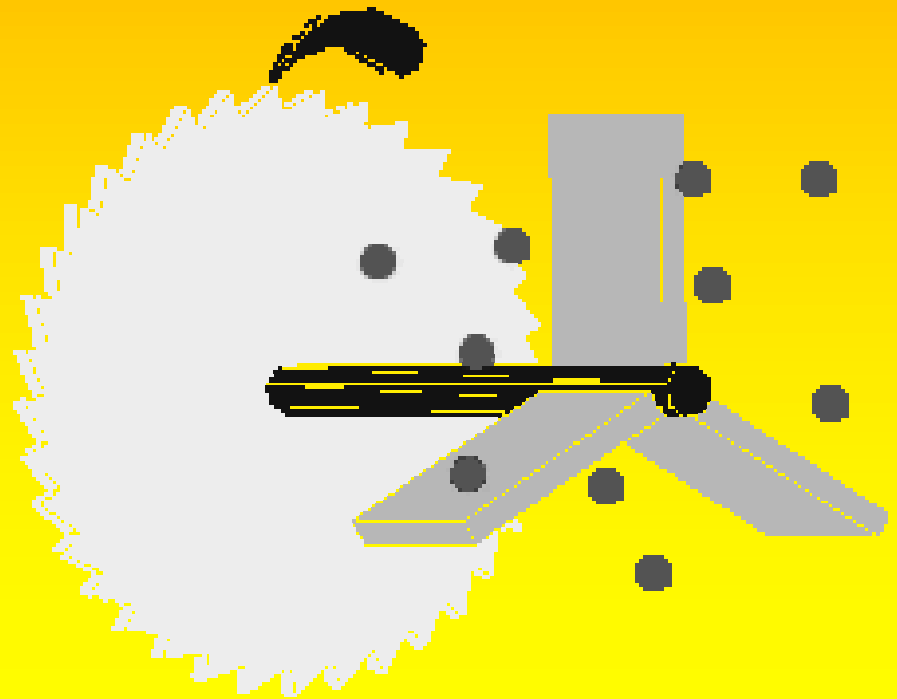
Introduction to the Topic of „Biomolecular Motors“

“A great challenge for the burgeoning field of nanotechnology is the design and construction of microscopic motors, that can use input energy to drive directed motion in the face of inescapable thermal or other noise” Peter Hänggi

Introduction to the Topic of „Biomolecular Motors“

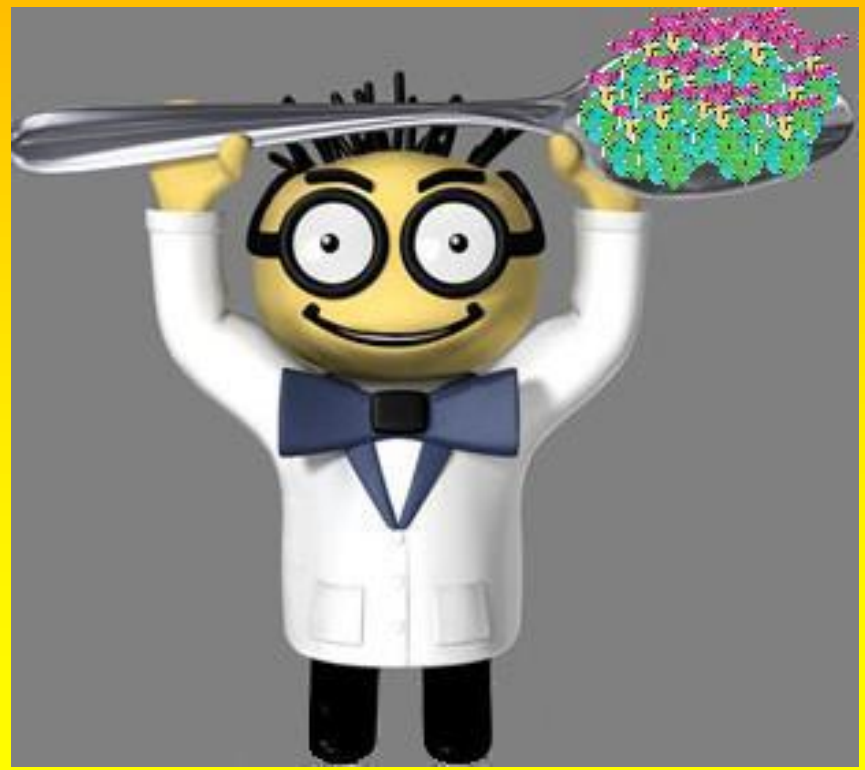
- **Feynman**:
  Random Bombardment is brought into Nonrandom Motion

  à basis for brownian motors



Introduction to the Topic of „Biomolecular Motors“

- Size of a Motor:
  150-750nm
- 1 tablespoon = 1Billion x 1 Billion Motors



Introduction to the Topic of „Biomolecular Motors“

General Mechanism of Motors:

Converting Chemical Energy into Mechanical Work

Introduction to the Topic of „Biomolecular Motors“

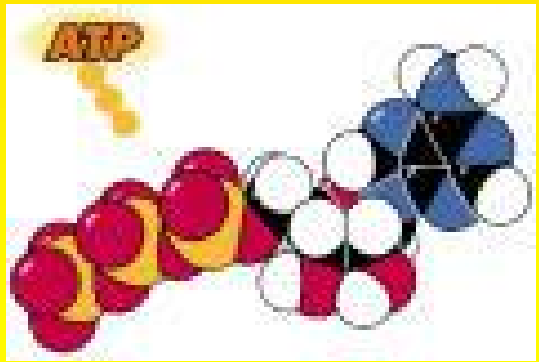
Montemagno:

- Constructed one of the first Nanomotors
- ATP is used as ‘fuel’
- 40min at 3-4 revolutions/seconds

Introduction to the Topic of „Biomolecular Motors“

Possible Energy Sources for Nanomotors:

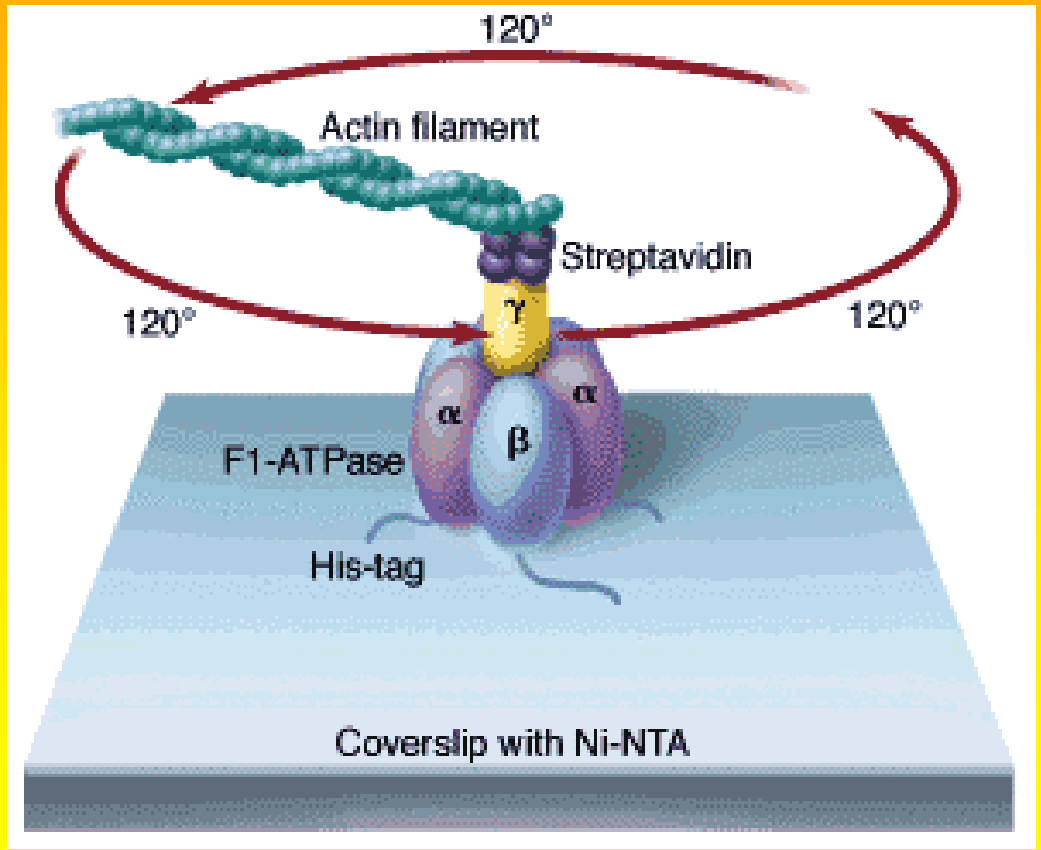
- Solar-Energy
- Acoustic Energy
- Electrical Energy
- **Chemical Energy, e.g. ATP**



How does this system work?

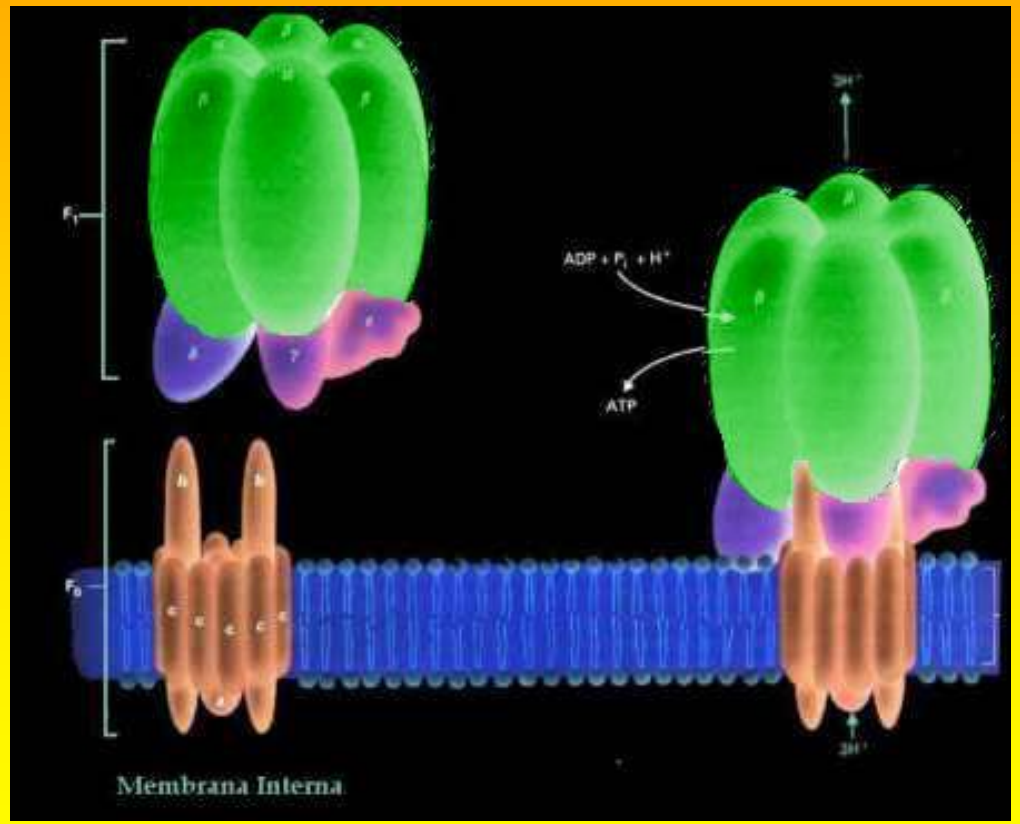
Principle of the Motors

- Motor: ATPase
- Propeller: Actin Filament

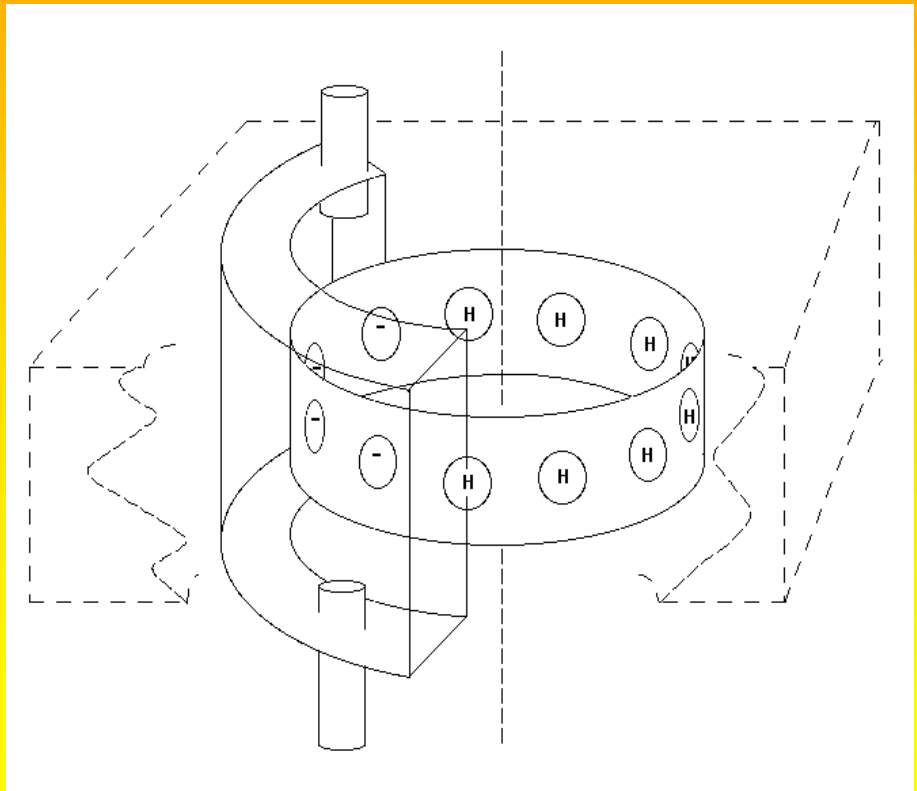


Role of ATPase

- F1 Part:
  Headpiece
- F0 Part:
  Membrane Protein

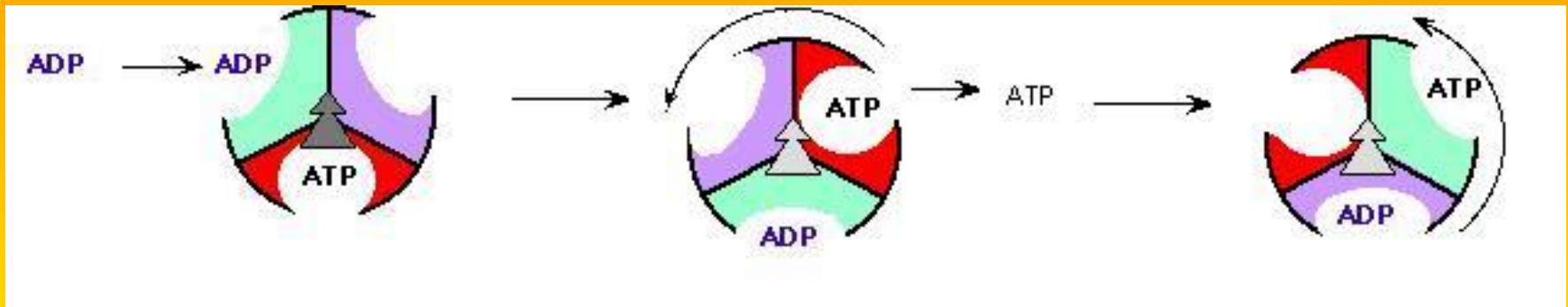


Role of ATPase – F0 Part



- Rotary Engine driven by Proton Force
- Electrical Voltage generated by the Concentration Difference Top to Bottom

Role of ATPase F1 Part



- 3 β-subunits (binding sites) are active in the ATP Synthesis out of ADP and Phosphate
- Rotation of F0 Part opens and closes β-subunits and thus leads to a clockwise rotation of F1 Part
- Product ATP is released

Role of ATPase

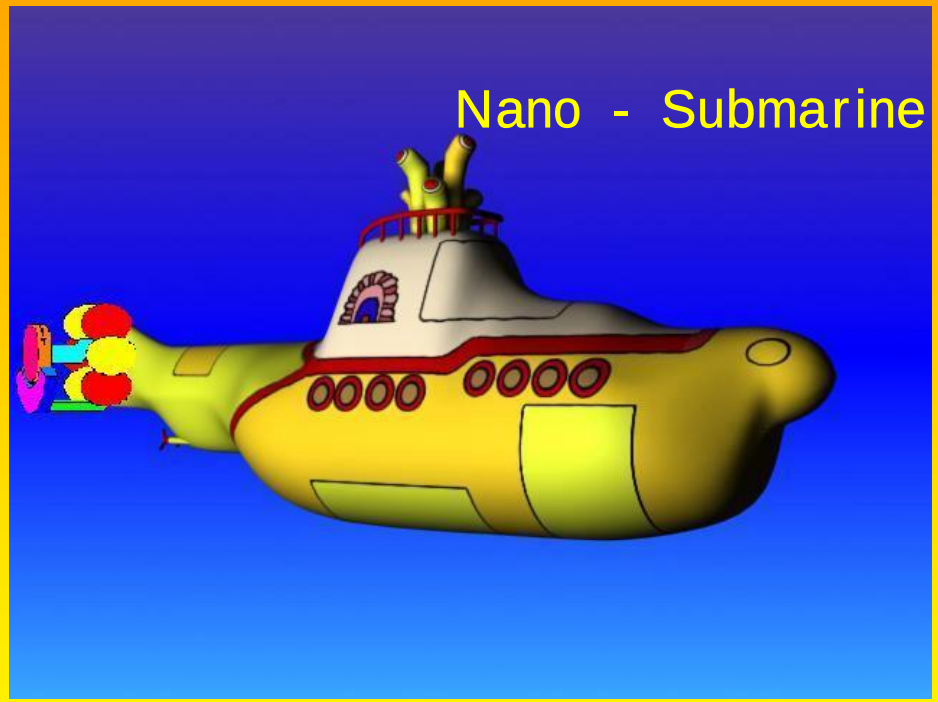
- In Case of Hydrolysis of ATP the F1 Part rotates counterclockwise

How Do the Motors Drive a Propeller?

Propeller and their Function

Propellers attached to ATPase:

Create Force, that drives Fluid backward and the Submarine forward



à Directed Movement

Properties of a Propeller

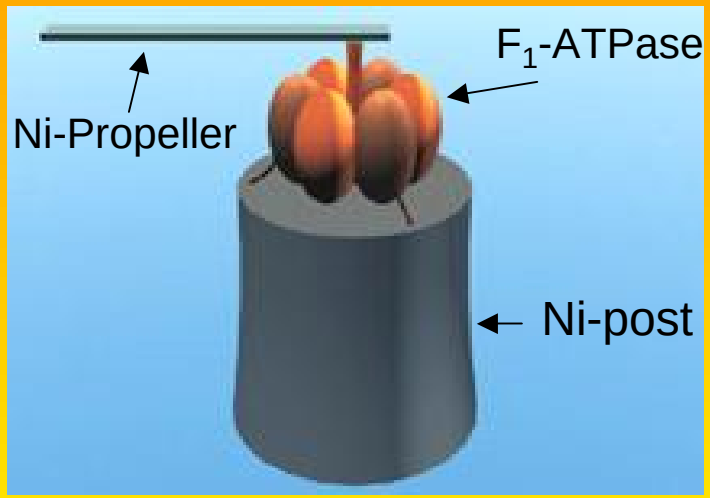
- Diameter:
  ~150nm
- Length:
  ~740-1400nm
- Material:
  Nickel (Ni)

ATPase-Protein with artificial Propeller

Problem:
Currently, Propellers do not have a Long Life Time!

How Connect a Propeller to a Biomolecular Motor?

Connection of Propeller

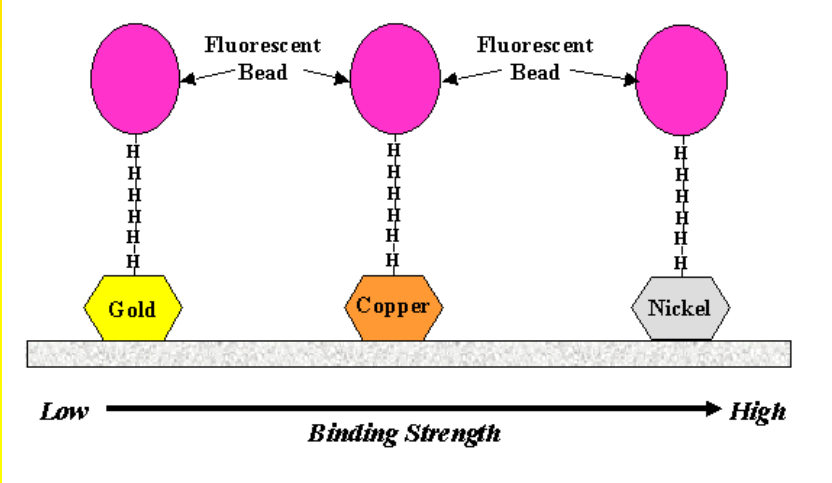


Problem:

Coupling of Biological (ATPase) with an Inorganic Component (Propeller)

à Nickel has high Affinity to Histidine

à Nickel used as Propeller-Coating Material



Why does this System work?

à Concerning Reynold´s Number and Brownian Movement

Why does this System work?

„Because small Devices have very large Ratios of Surface to Volume, Surface Effects – Both good and bad – become much more important for Them then for large Devices.“ Whitesides

Reynold´s Number (RN)

- Most important dimensionless Number in Fluid Dynamics
- Ratio of Inertial Forces ($v_s r$) to Viscous Forces (μ/L)
- Used for Determination of Laminar (low RN) respectively Turbulent (high RN) Flow

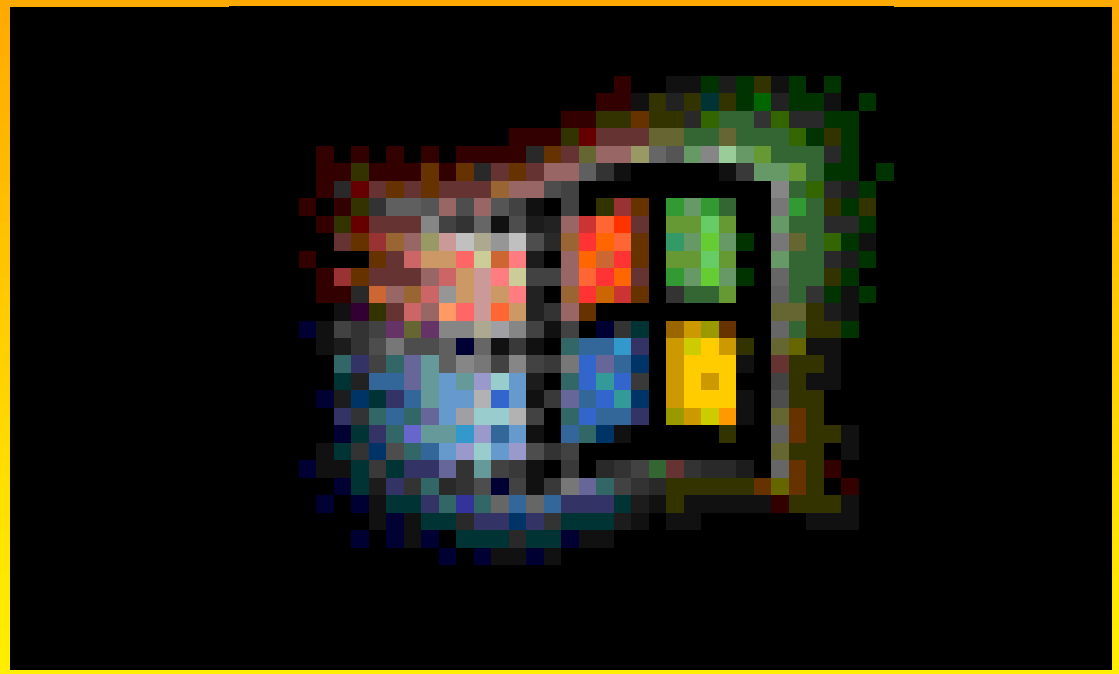
Reynold´s Number (RN)

- Human Swimmer: RN = 10^{5}
- Sperm: RN = 10^{-5}

Example:

A Man to be Swimming at the same Reynold´s Number as his own Sperm, would have to be placed in a swimming Pool full of Molasses and then be forbidden to Move any part of his Body faster than 1cm/min, roughly the speed of the minute-hand of a large wall Clock.

Brownian Movement



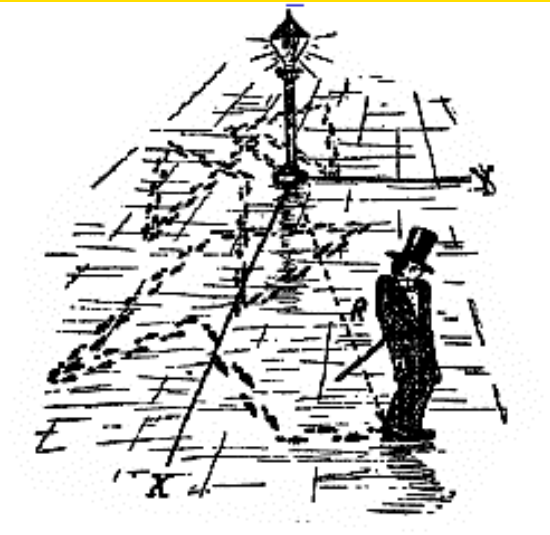
- Botanist observed jiggeling Movement of Pollens under Microscope

  à Passive Movement

Brownian Movement – Random Walk

- Collosions with Molecules are all random

à Bombardment Forces are not driving in a Definite Direction



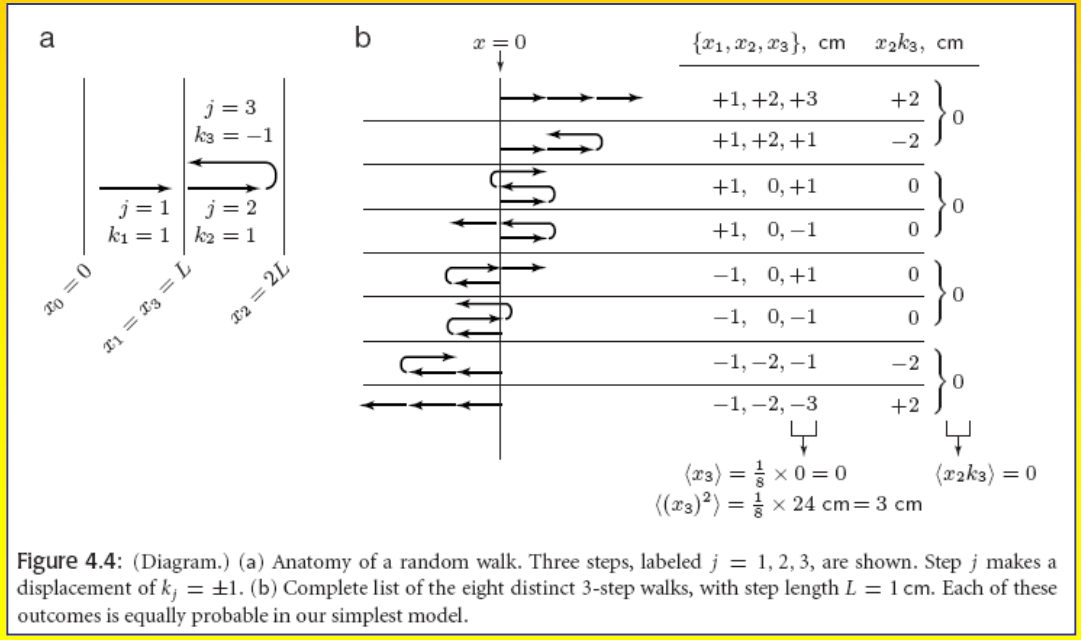


Figure 4.4: (Diagram.) (a) Anatomy of a random walk. Three steps, labeled $j = 1, 2, 3$, are shown. Step j makes a displacement of $k_j = \pm 1$. (b) Complete list of the eight distinct 3-step walks, with step length $L = 1$ cm. Each of these outcomes is equally probable in our simplest model.

Application?

Application in Biology and Life Science

- Such motors could provide the power for moving (molecular or cellular) hybrid systems which move or "swim" through a solution or body.

- Nanorobots could detect anomalies reflecting the presence of interior hematomas, lipomas, edemas and hydromas

Application in Biology and Life Science

- Linear motion can mimick the stretching and contraction of muscle fibers and could in the future power artificial muscles
- Directing a therapeutic agent to a site of disease

„What would happen if we could arrange atoms one by one the way we want them?“ Richard Feynman

Ethical Considerations

- All powerful technologies are double-edge swords
  - à beside all the positive aspects mentioned before there are negative effects

- Misuse: Eternal Youth
- Abuse: Biowarfare

„The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big.“

Richard Feynman

Any Questions?

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