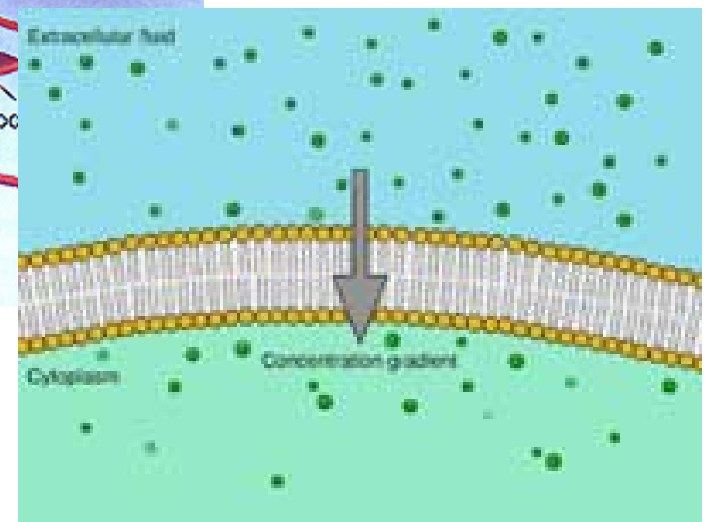
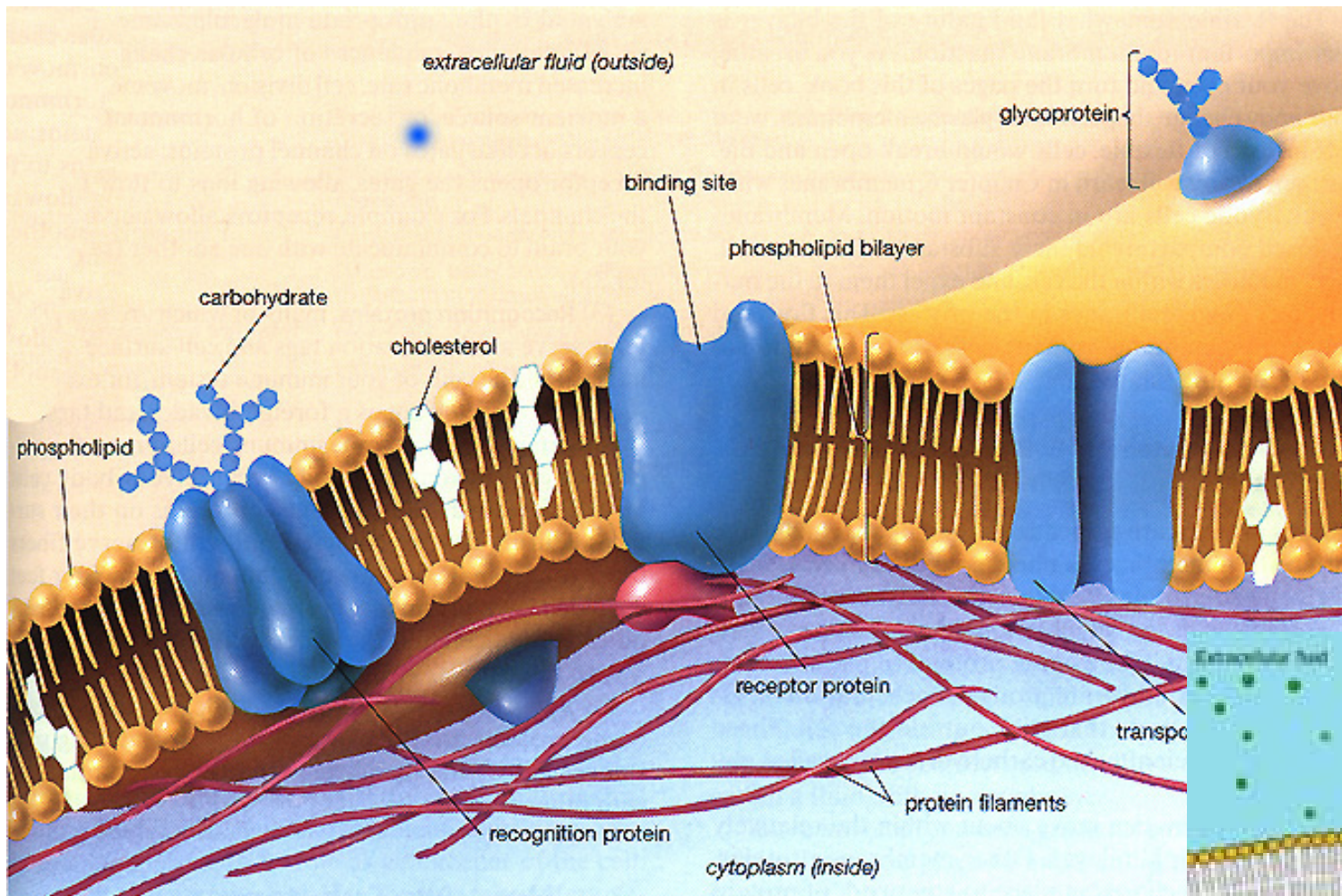


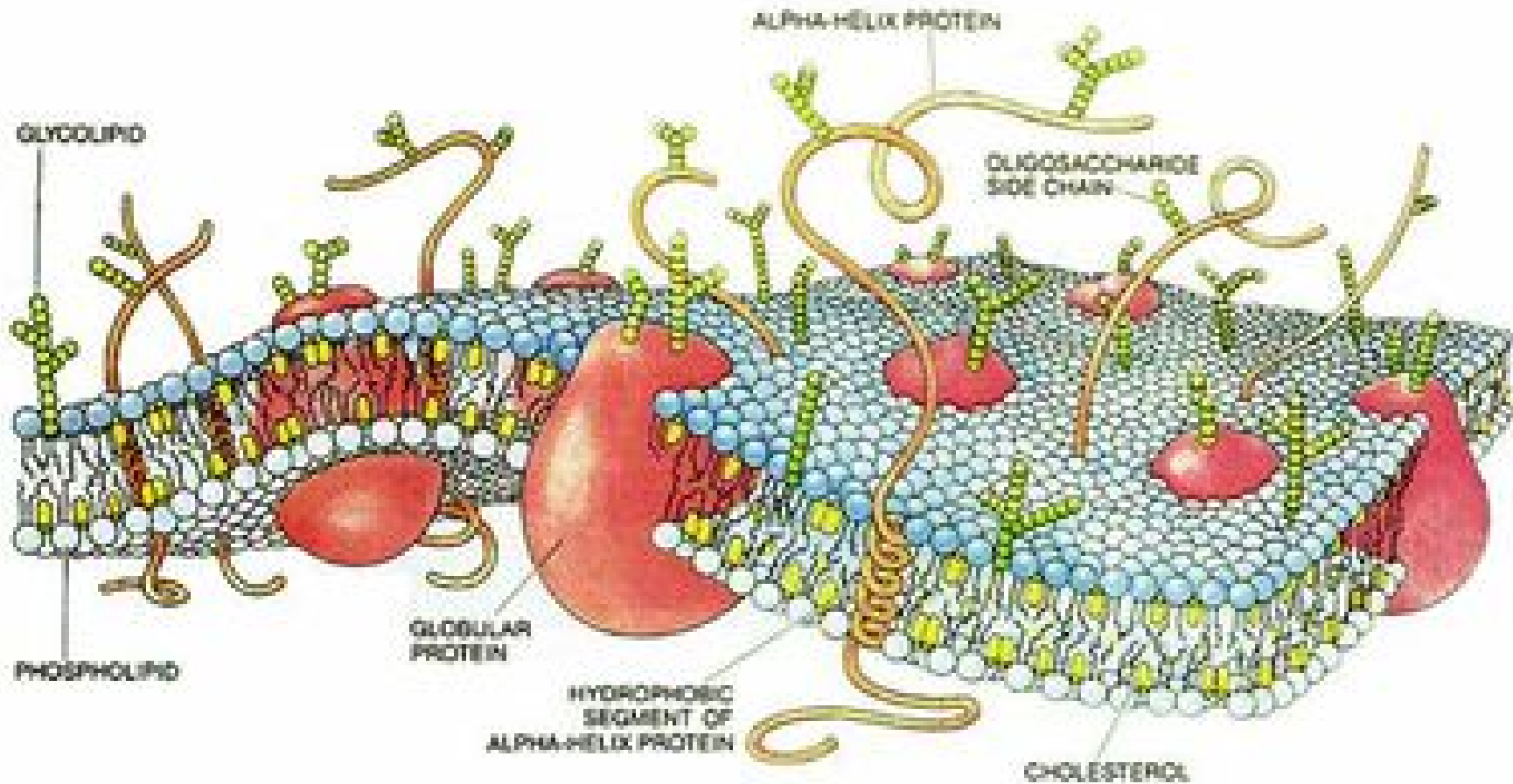
# Biomolekulare Systeme

- Membran (Wand/Kanal)
- Proteine (Funktion/Gerüst)
- Enzyme
- Brennstoffe (ATP)
- Photosyntheseapparat
- Protonentransfer/Sehvorgang
- Molekulare Motoren

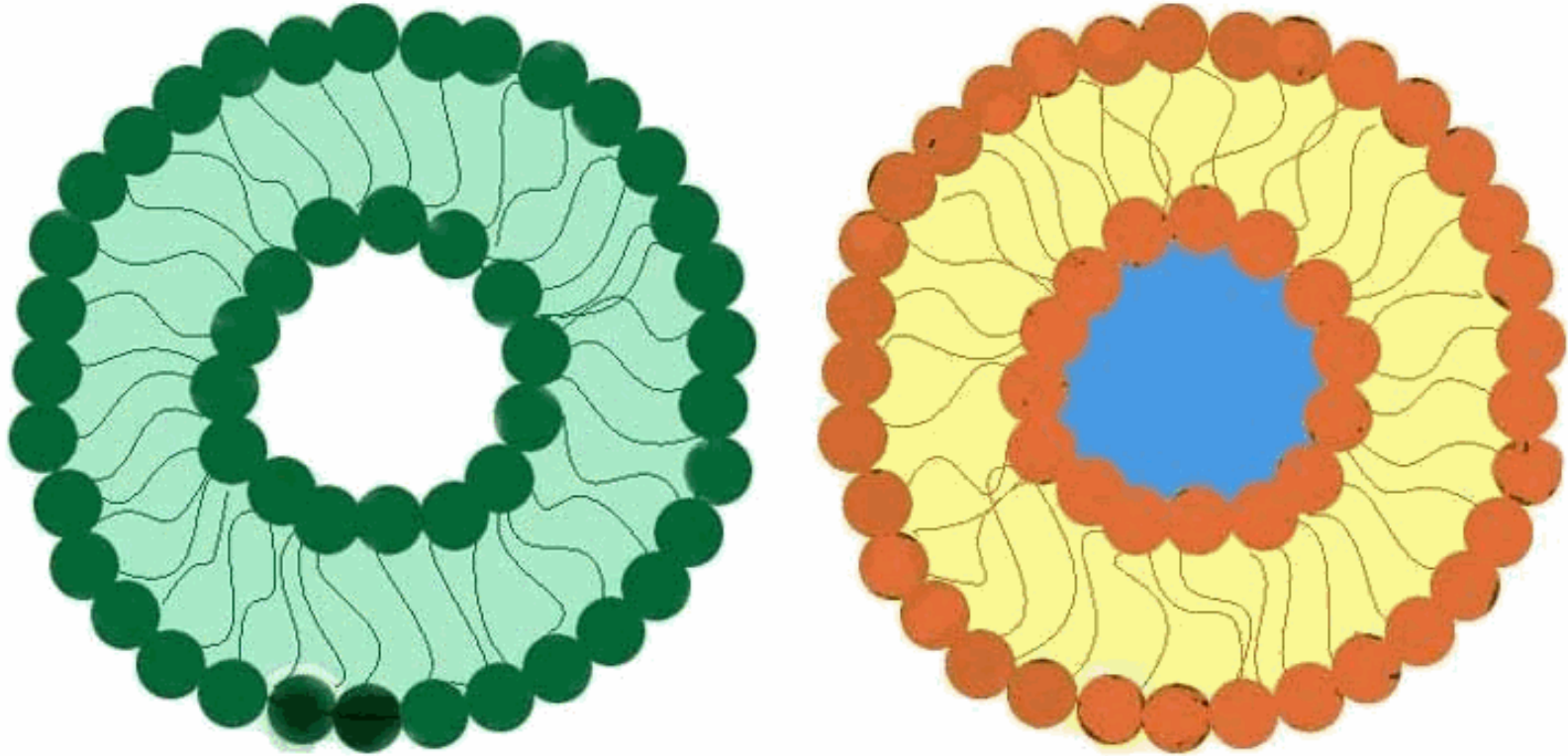
# Membran



# Membran



# Fusion von Zellen



# Proteine

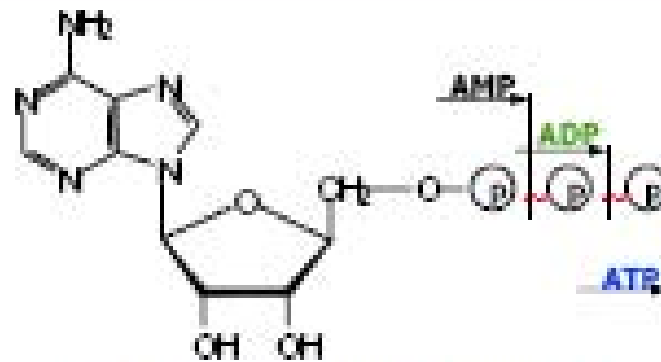
- Eiweißmoleküle Transport)
  - Myosin
  - Kinesin
  - Dyneine

Schaniere, Hebel, Federn, Kupplung

# Proteine

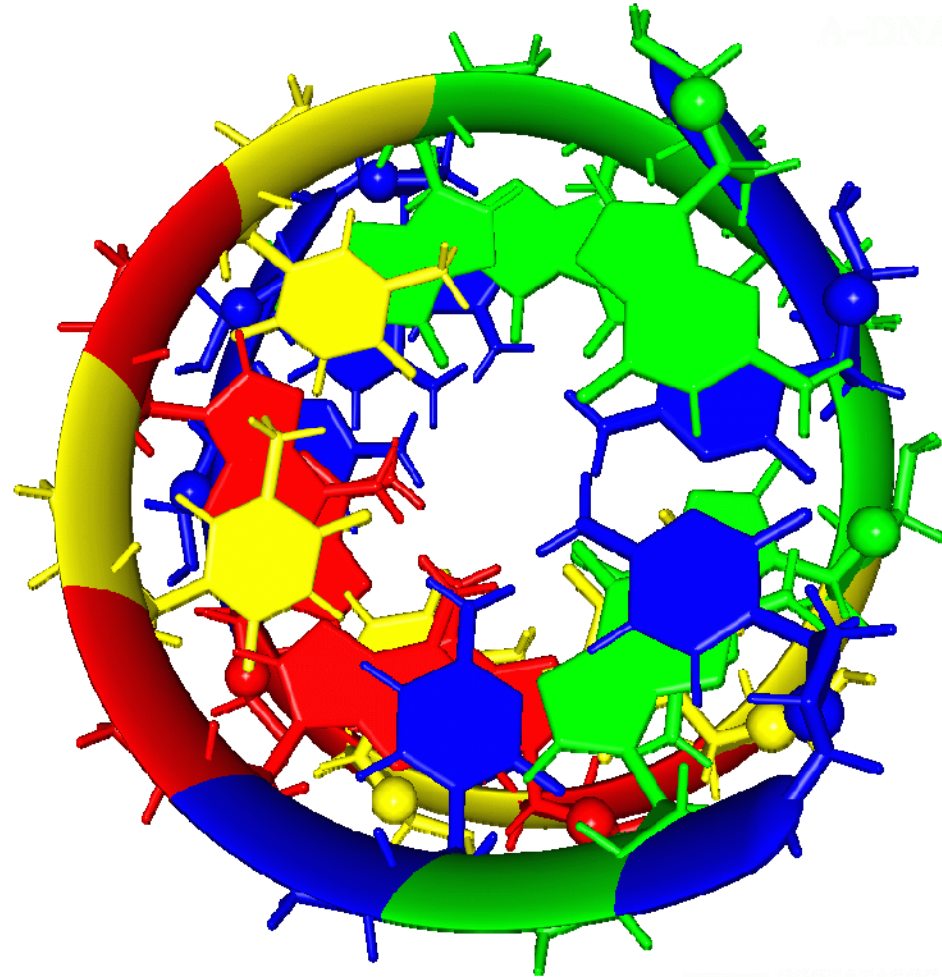
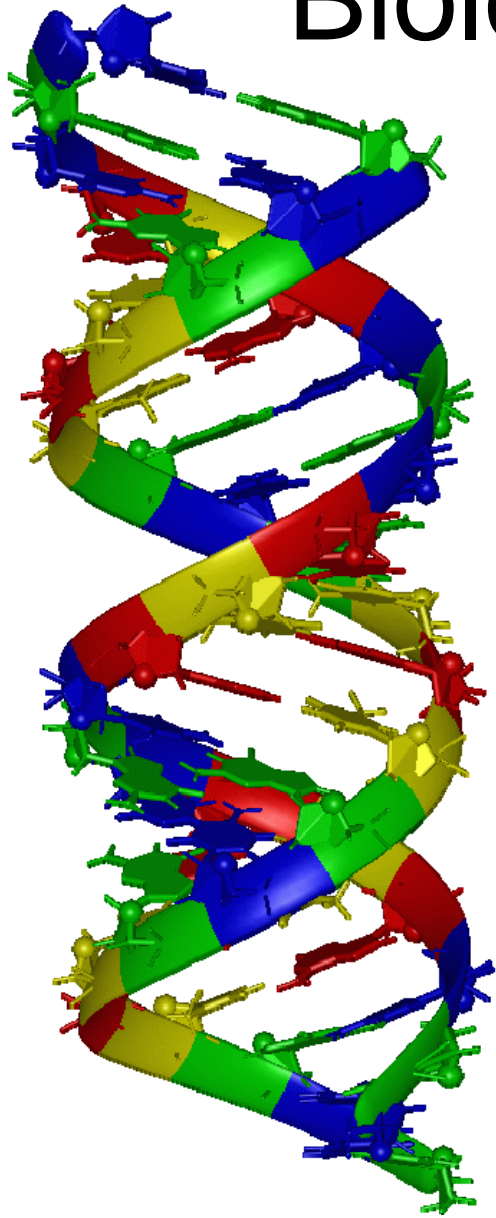


# Brennstoff: ATP



~ Energiereiche Bindung

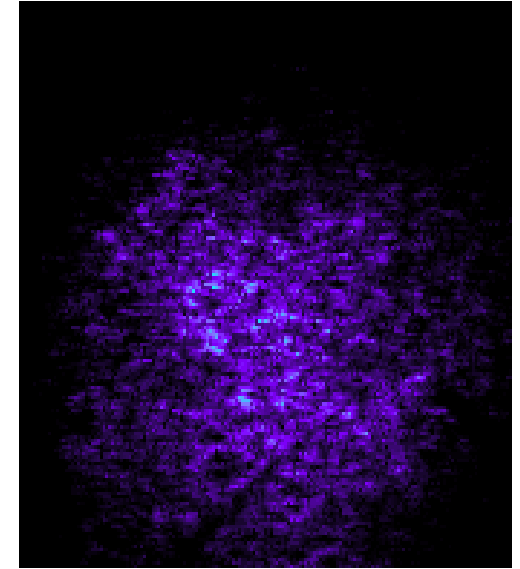
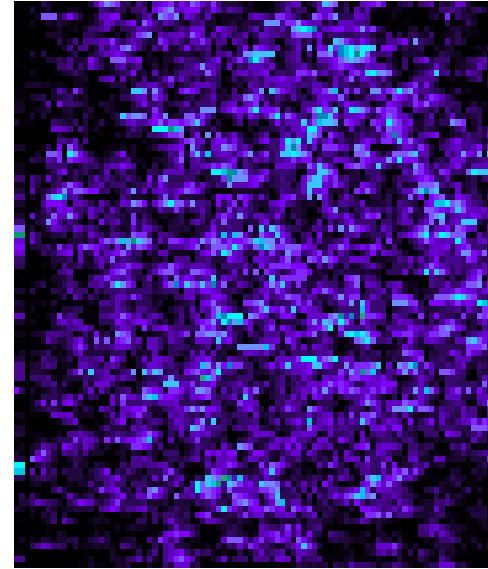
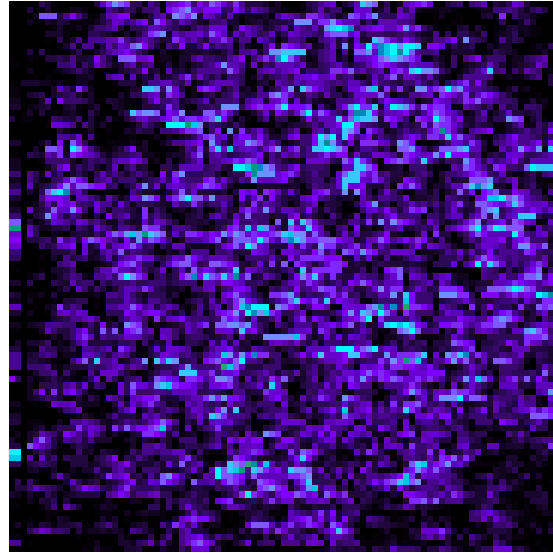
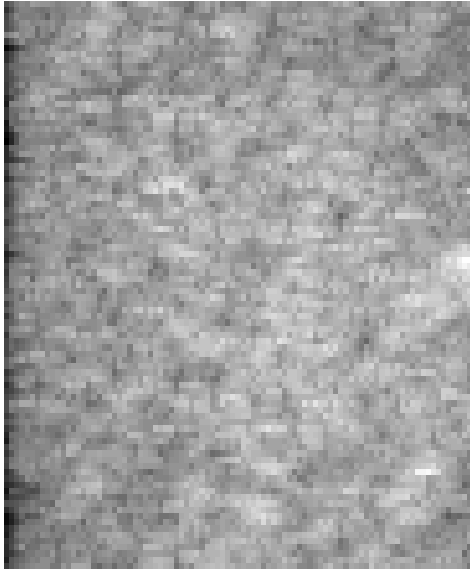
# Biologische Nanowelt





# Virusinfektion

Bräuchle, LMU München

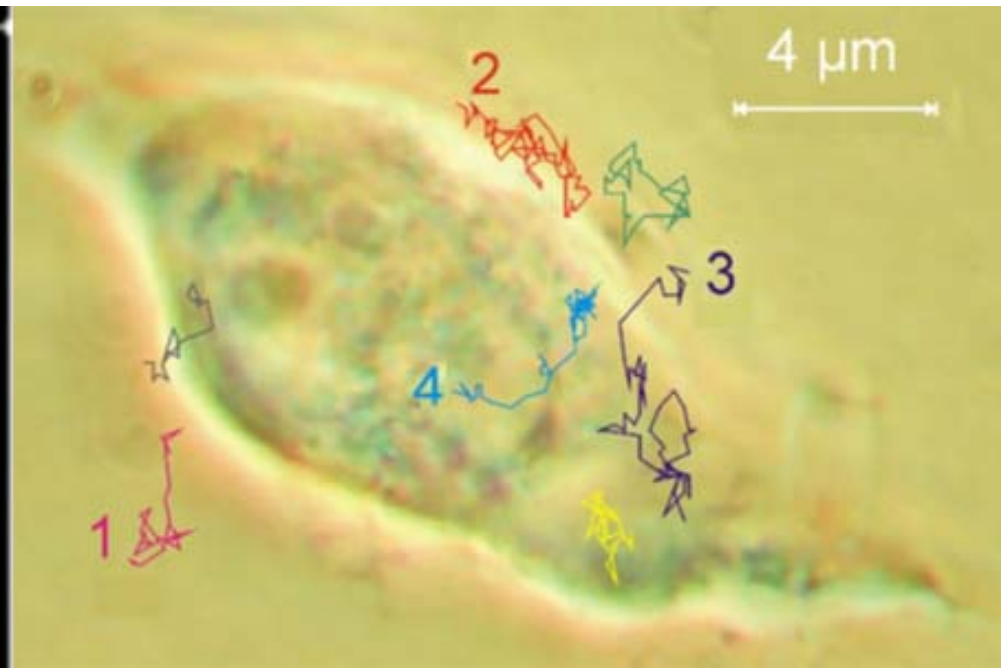
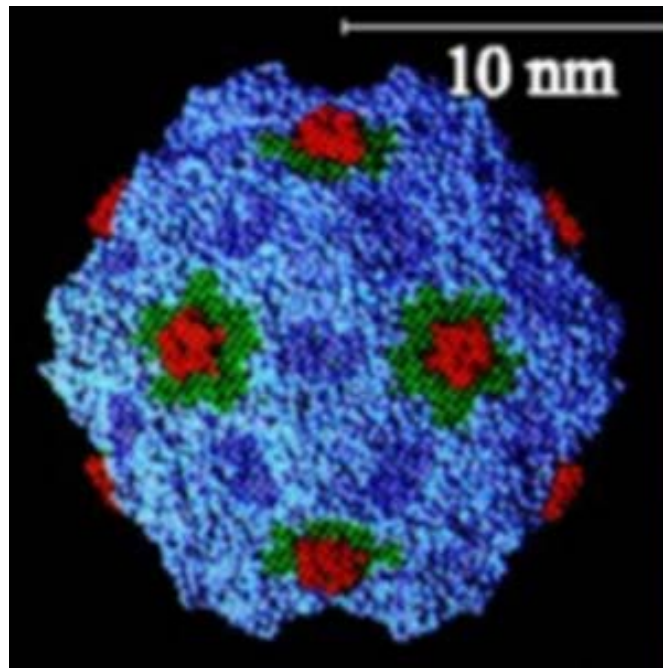


1: Kontakt

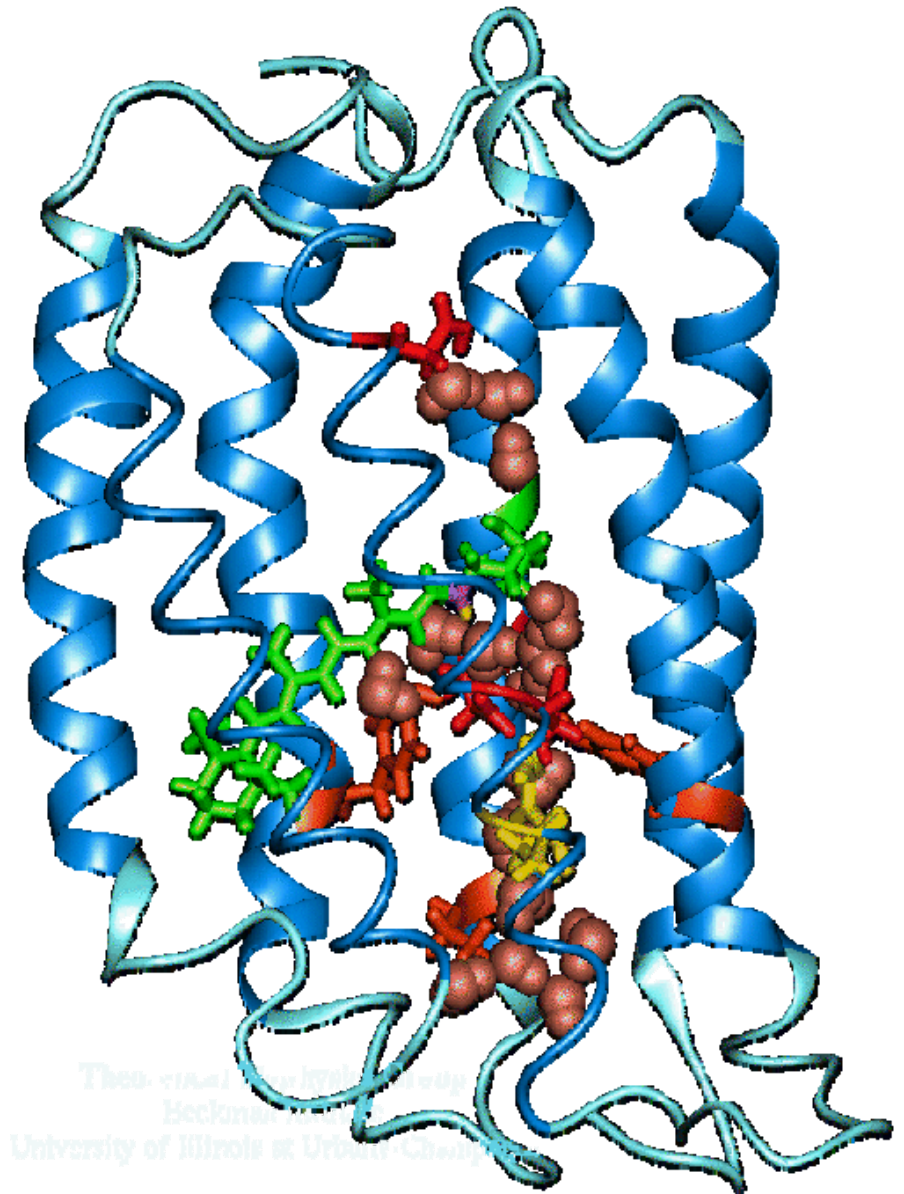
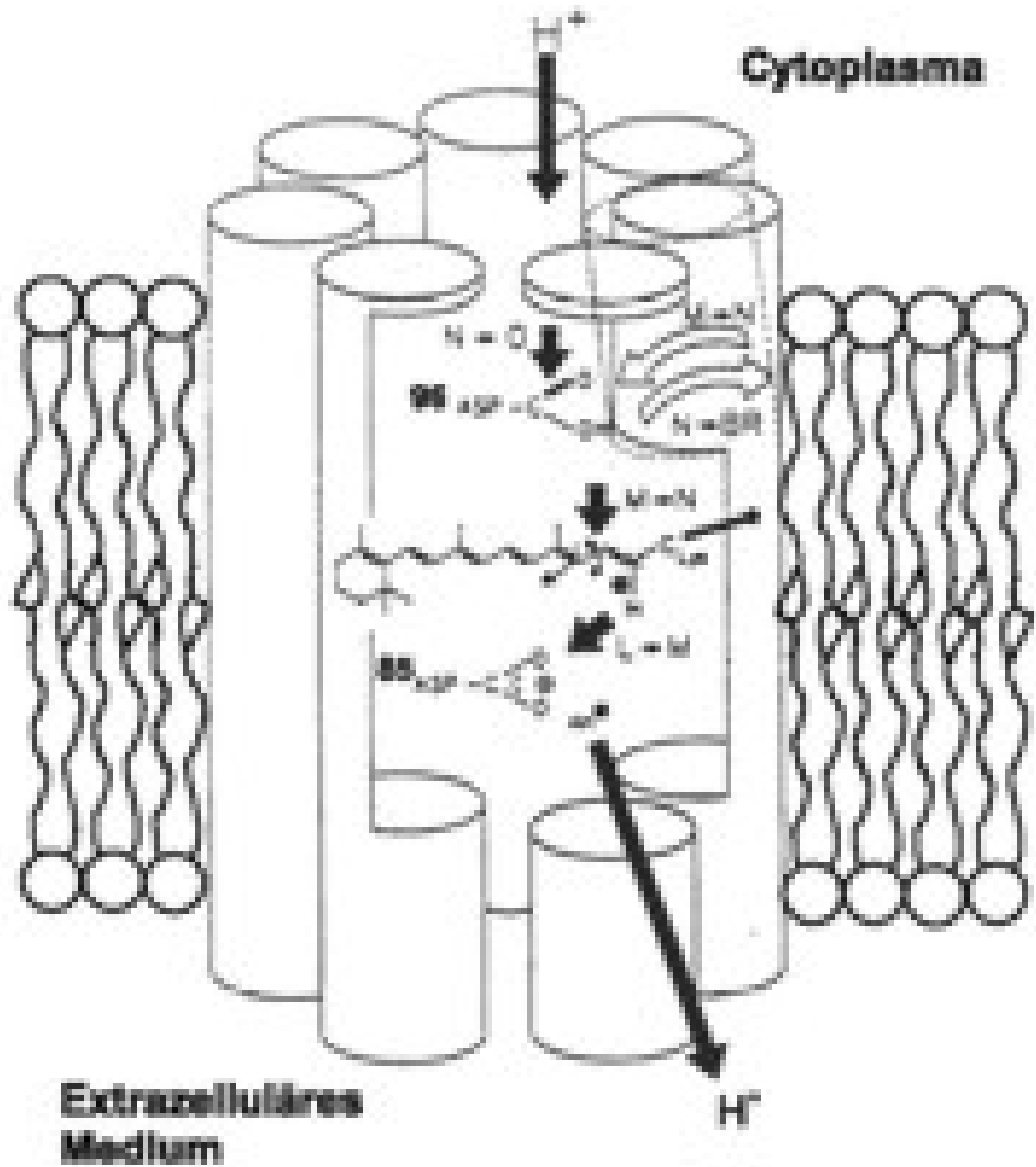
2: Tasten

3: Eindringen

4: Infektion

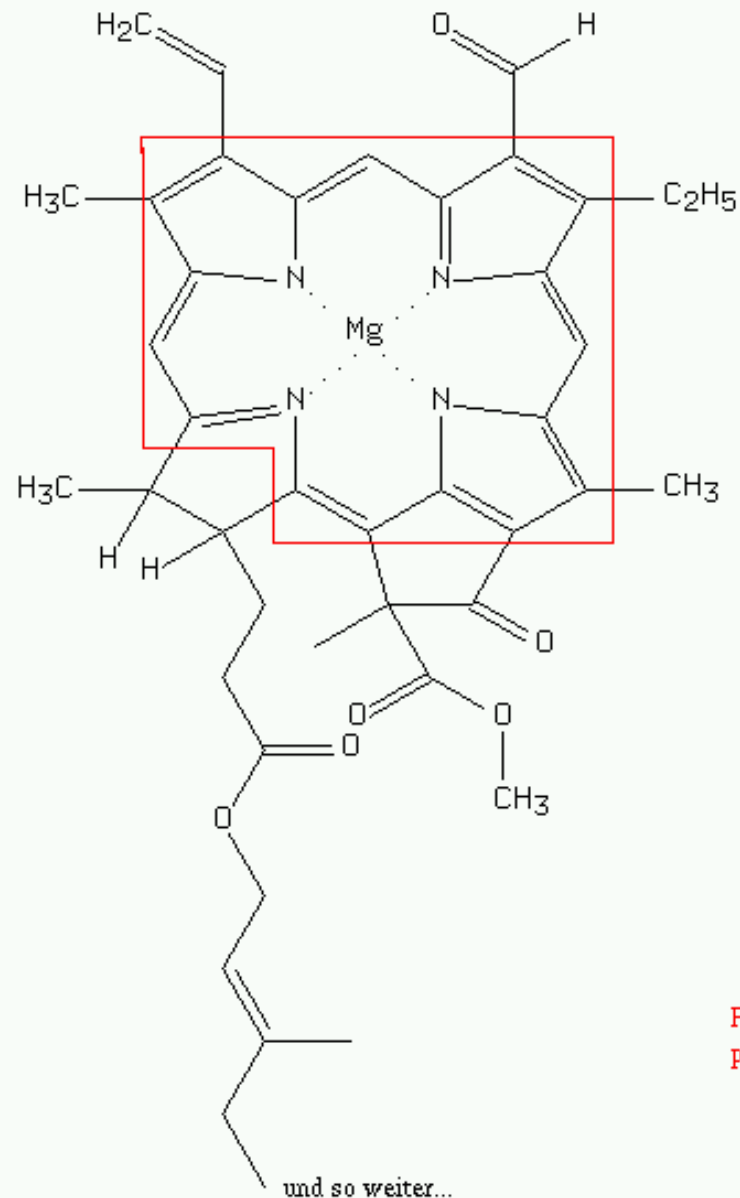


# Protonenpumpe: Bacteriorhodopsin

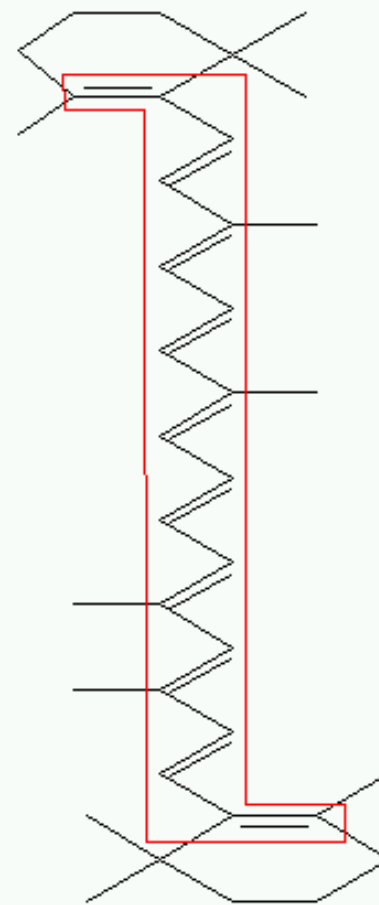


## Lichtabsorbierende Moleküle

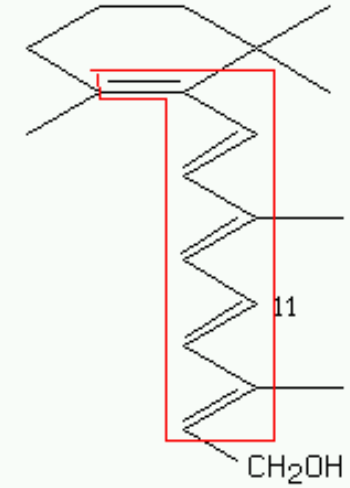
Chlorophyll b



$\beta$ -Carotin



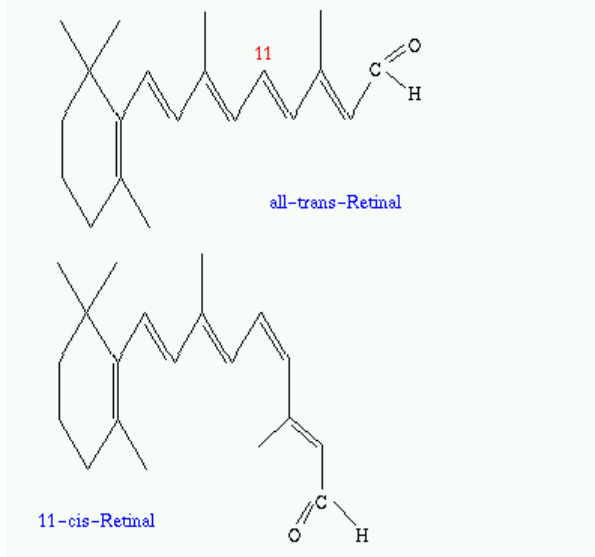
Retinol (Vitamin A)



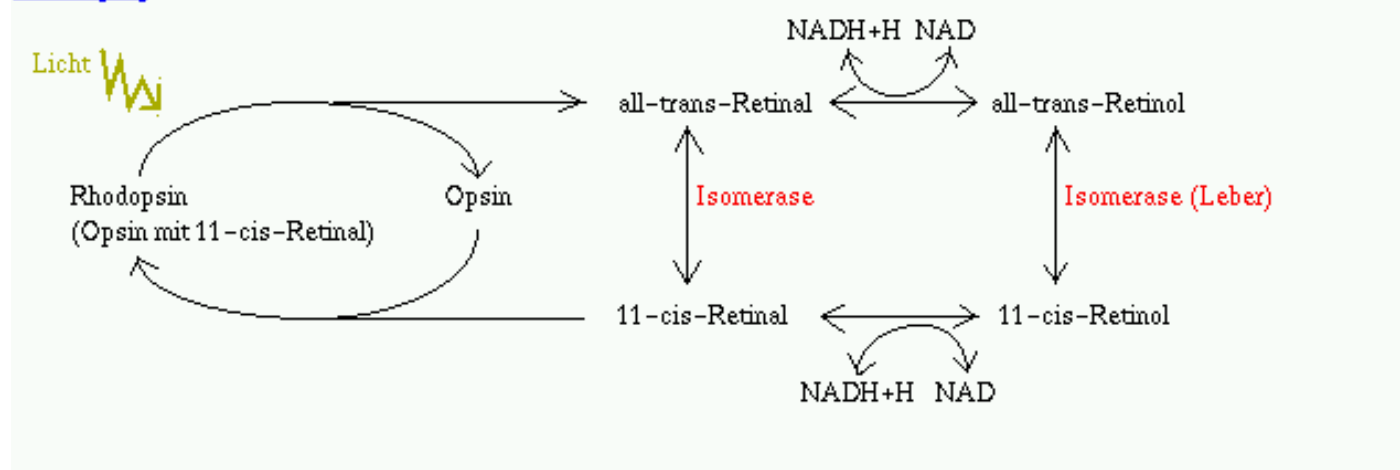
Photochemische Reaktionen laufen an den Stellen der delokalisierten pi-Elektronen ab.

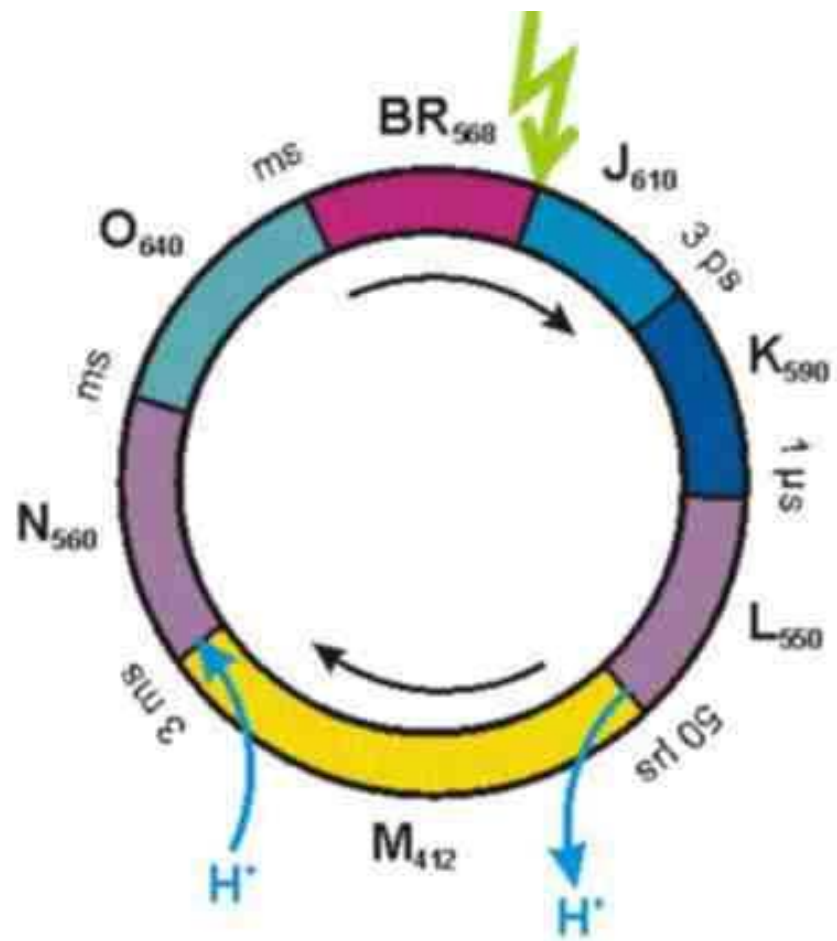
# Retinal - Schaltung

## Retinal



## Sehvorgang

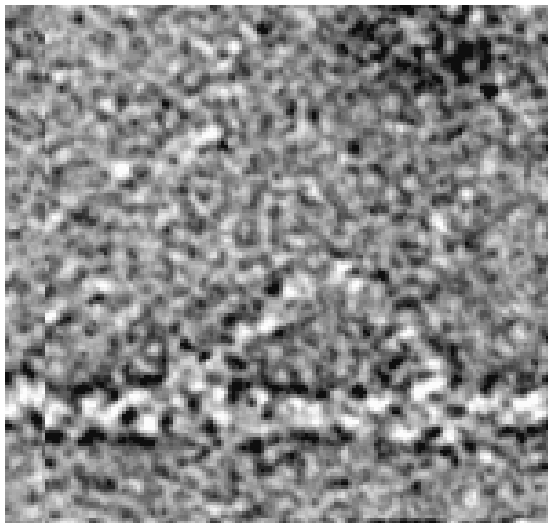




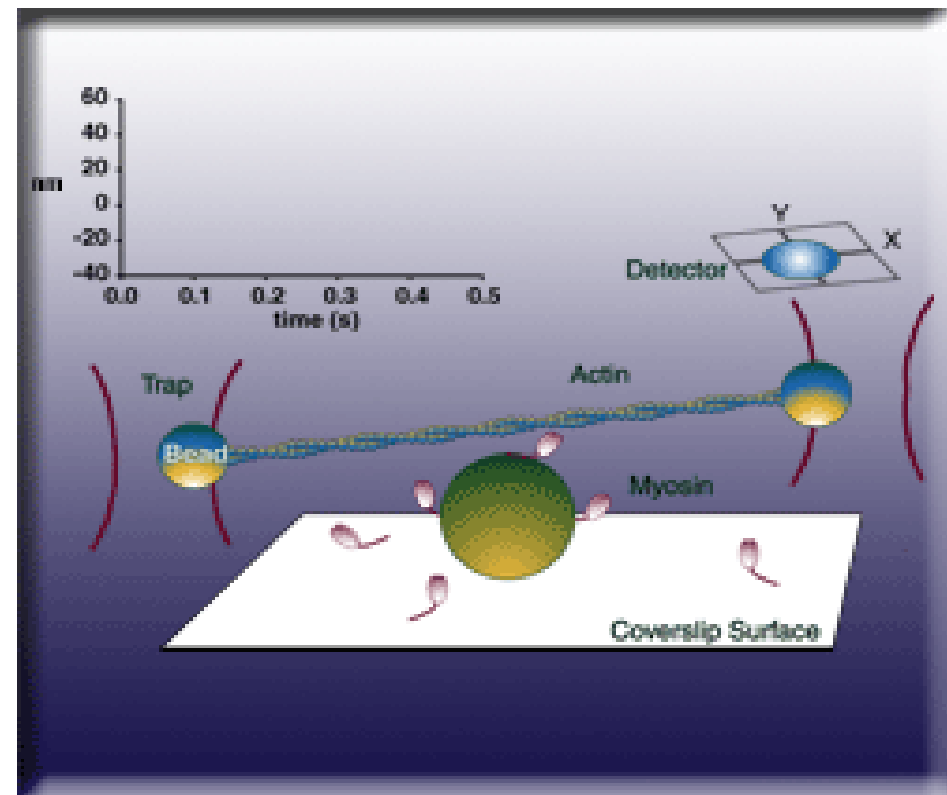
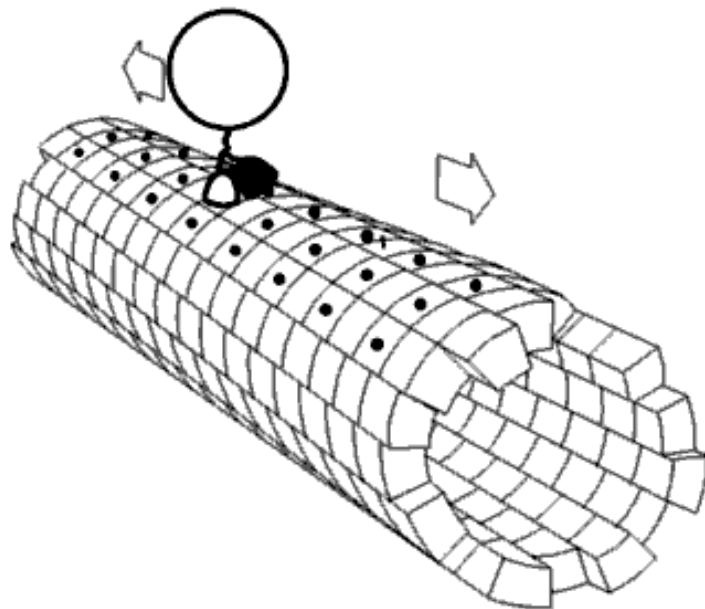
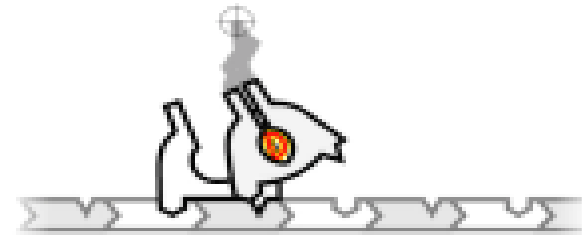
# Molekulare Motoren

- Transport von Zellbaustoffen
- Zellteilung
- Muskelbewegung
- Geißelbewegung (Sperma)

# Nanometer - Motoren



The Muscle Group, Leeds 2000



# Biomolekulare Motoren

## Eigenschaften

- Kleine Schritte
- Veränderungen der Proteinkonformationen werden in gerichtete Bewegungen umgewandelt

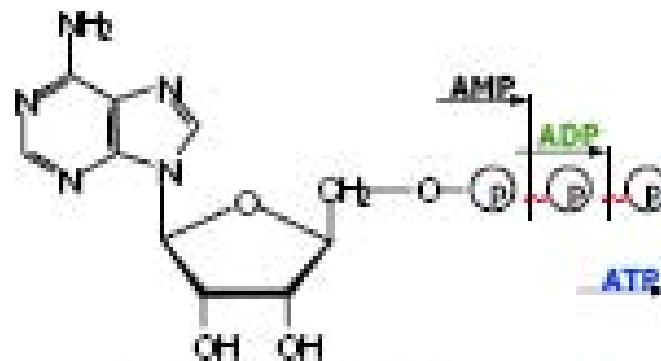
## Strategien

- Bewegungen über größere Distanzen entlang einer „Schiene“ (Aktin- und Mikrotubuli-Proteinfasern): **Linearmotoren**  
Bewegung durch Veränderung der Affinität von Motorproteinen zu den Schienen über ATP-Hydrolyse
- Für bakterielle Bewegung: **Rotationsmotoren**  
Treibstoff ist ein Protonengradient, der über den "ATP-Synthase-Mechanismus" in eine Drehbewegung umgewandelt wird

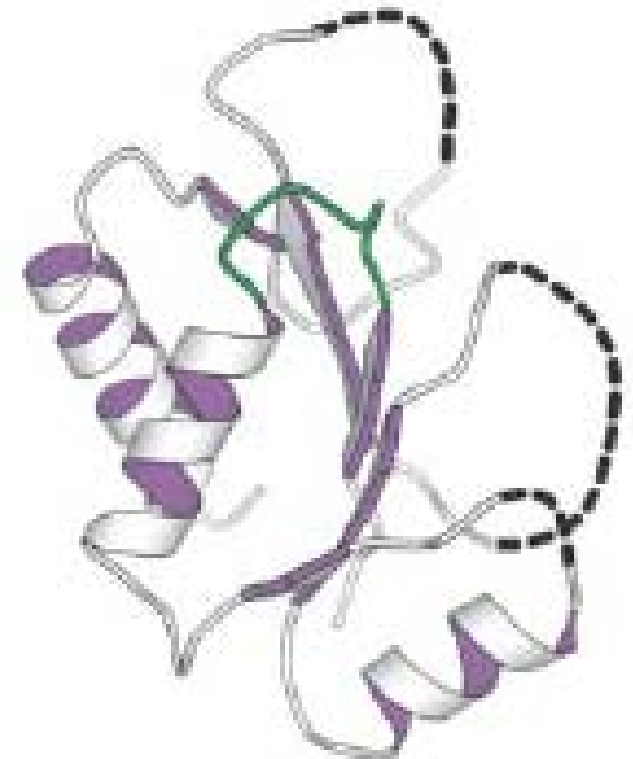


# Biomolekulare Motoren

- Grundlage für alle Bewegungsvorgänge sind die gleichen biochemischen Mechanismen
- Schlüsselrolle: Umwandlung der chemischen Energie aus ATP in kinetische Energie mittels "P-Schleife ATPasen"

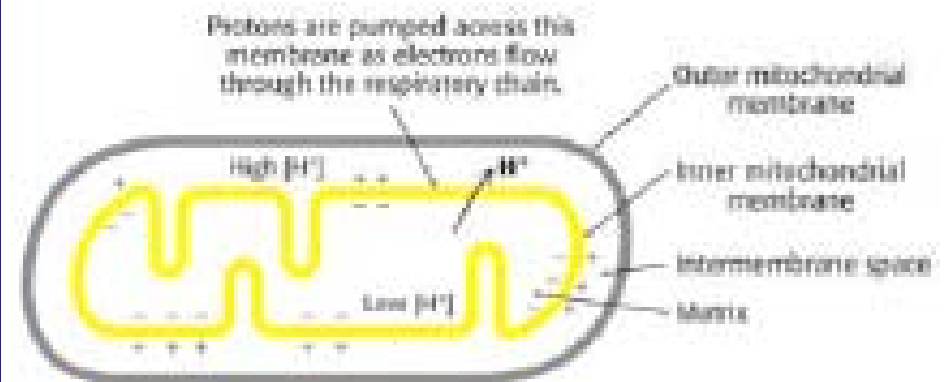


~ Energiereiche Bindung



# ATP-Synthase

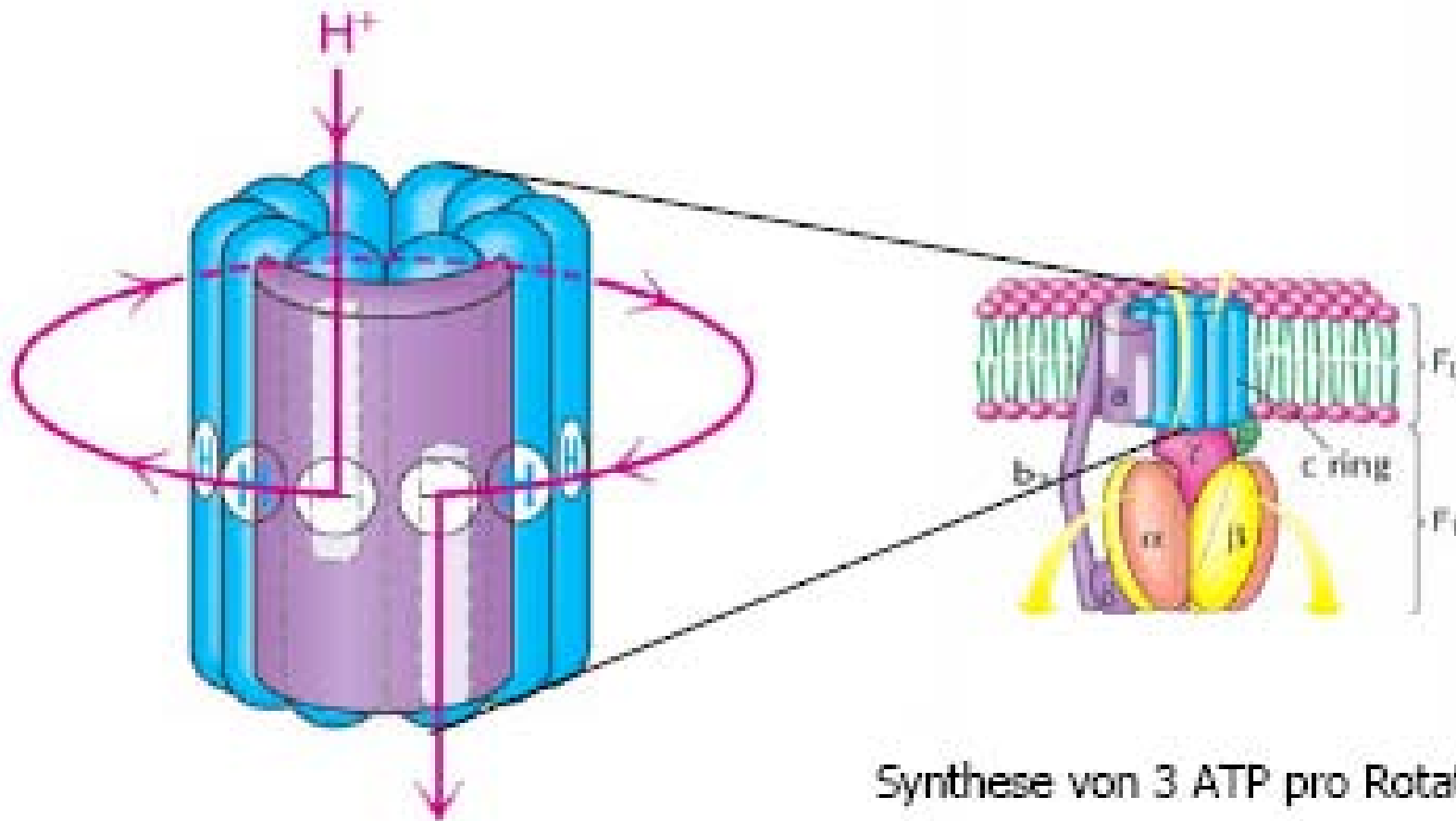
- „proton motive force“ = pH-Gradient + Membranpotential  
 $\Delta p = 0,224 \text{ V} = 21,75 \text{ kJ/mol Protonen}$
- pH-Wert an Außenseite der Membran um 1,4 Einheiten niedriger
- OH<sup>-</sup>-Ionen an Innenseite, H<sup>+</sup>-Ionen an der Außenseite der Membran  
⇒ Membranpotential: 0,14 V
- Protonenfluß treibt über ATP-Synthase die ATP-Synthese an



## Protonenpotential und ATP sind ineinander umwandelbar

- Hydrolyse von ATP:  $\text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{P}_i + \text{H}^+$      *ATPase*
- Synthese von ATP:  $\text{ADP} + \text{P}_i + \text{H}^+ \rightleftharpoons \text{ATP} + \text{H}_2\text{O}$      *ATP-Synthase*
- ⇒ Transportvorgänge, Geißelbewegungen, Biosyntheseprozesse
- ⇒ Nanobiotechnologische Anwendungen

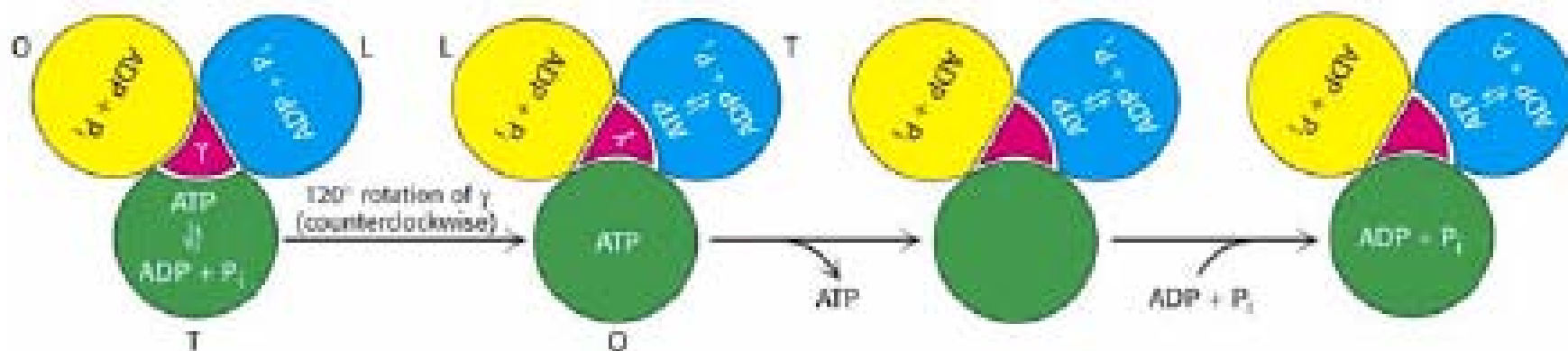
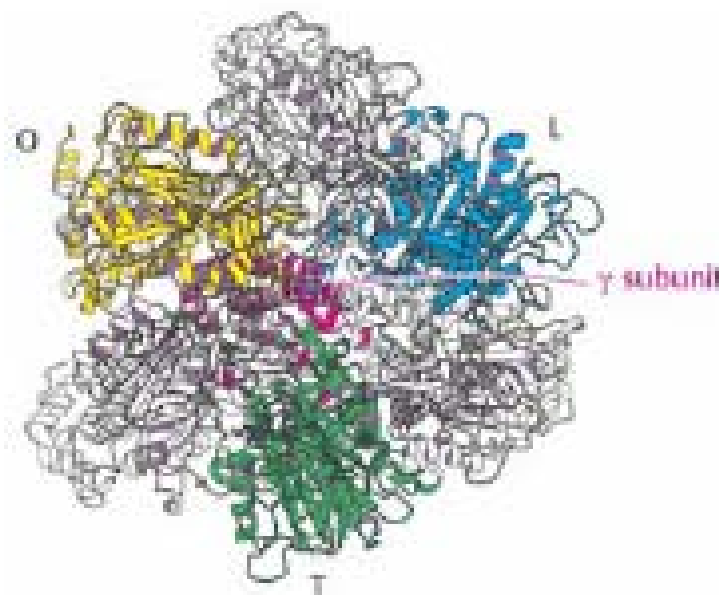
## Protonenfluß :: ATP-Synthese



Protonenfluß um den c-Ring treibt ATP Synthese durch die über die  $\gamma$ -Untereinheit vermittelte Konformationsänderung in den  $\alpha$ - und  $\beta$ -UE.

# ATP-Synthase : Binding – Change – Mechanismus

- Protonenfluß führt über Rotation von  $\gamma$  zu Konformationsänderungen in den drei katalytischen  $\beta$ -Untereinheiten.
  - Wechsel zwischen drei Formen mit unterschiedlichen Affinitäten
    - T = ATP stark gebunden
    - L = ATP oder ADP +  $P_i$  locker gebunden
    - O = offene Form
- ⇒ Freisetzung von ATP

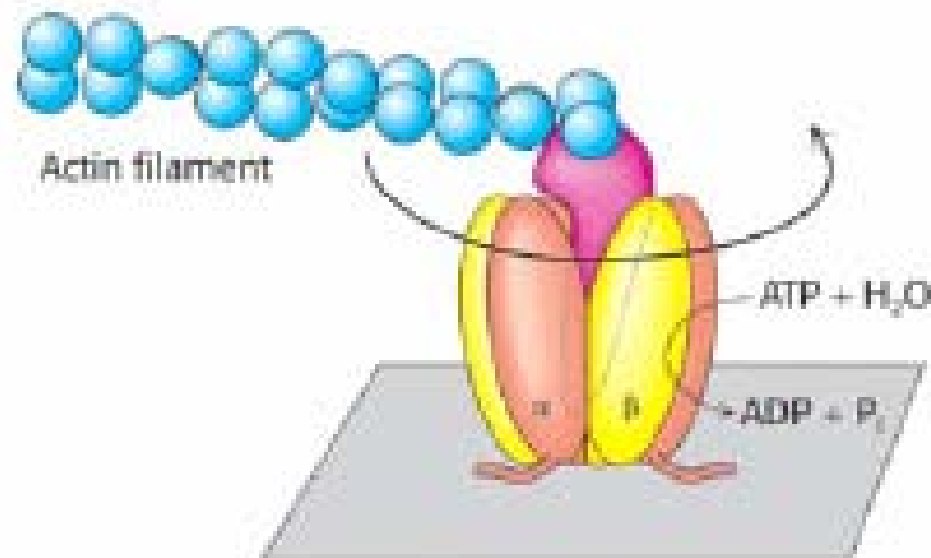


# Rotationskatlyse

## Kleinsten molekularer Motor der Welt

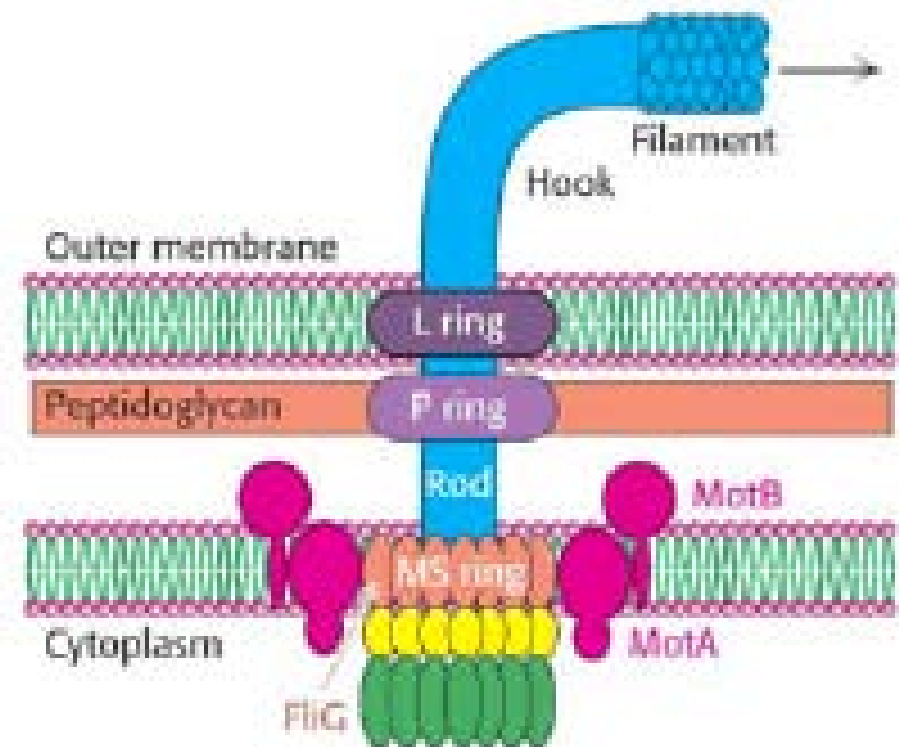
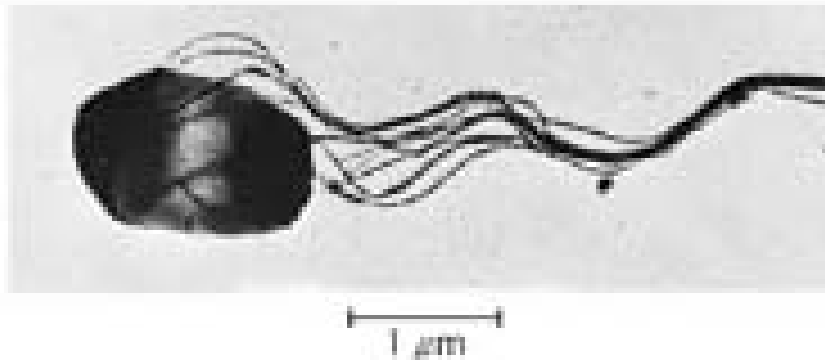
Experimenteller Aufbau:

- klonierte  $\alpha_3\beta_3\gamma$ -Untereinheiten
  - $\alpha_3\beta_3$ -UE mit His-tag; Immobilisierung an Ni-Oberfläche
  - Kopplung der  $\gamma$ -Untereinheit mit fluoreszenzmarkiertem Aktinfilament
- bei ATP Zugabe Drehbewegung unter Mikroskop sichtbar

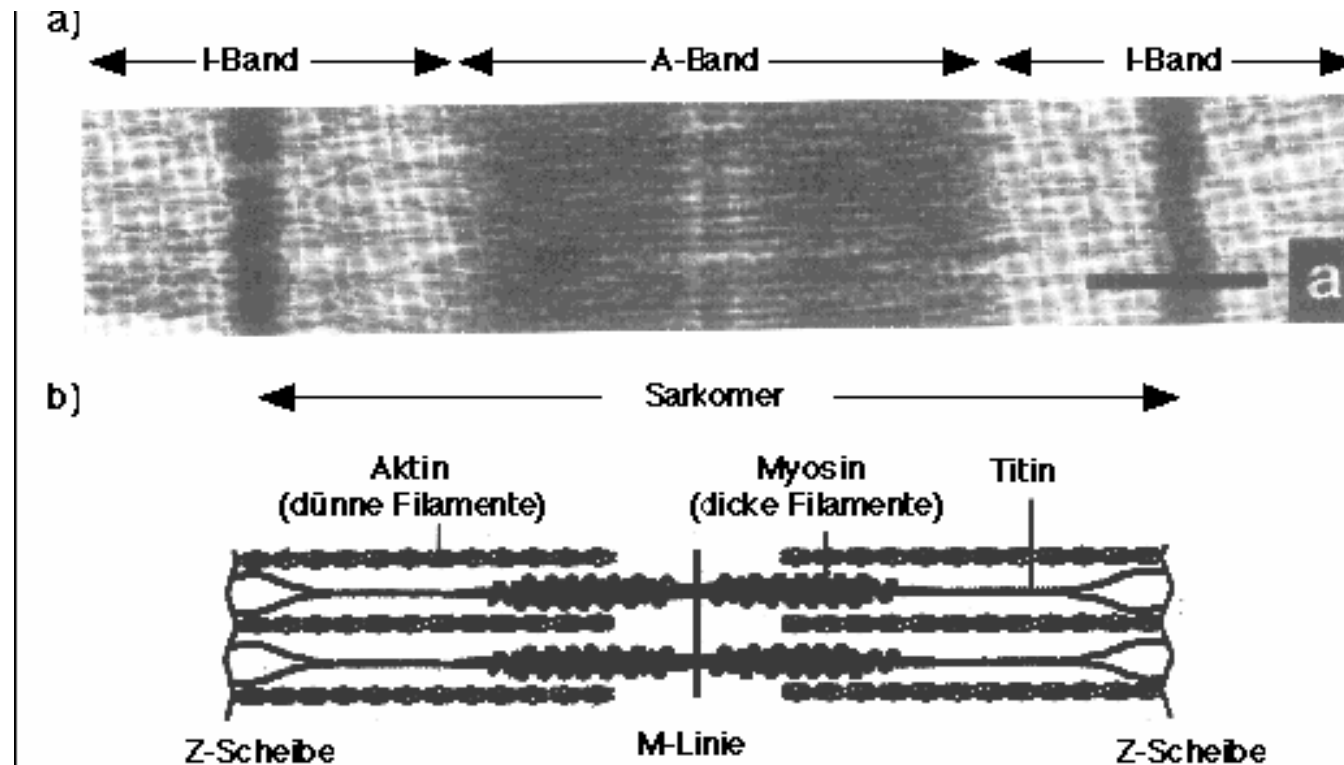


# Bakterienflagellen

- Bakterien bewegen sich mittels rotierender Flagellen
- Geschwindigkeit: bis  $25 \mu\text{m}/\text{sek}$  = 10fache der Zellenlänge; umgelegt auf Menschen  $17 \text{ m}/\text{sek} \approx 61 \text{ km}/\text{h}$

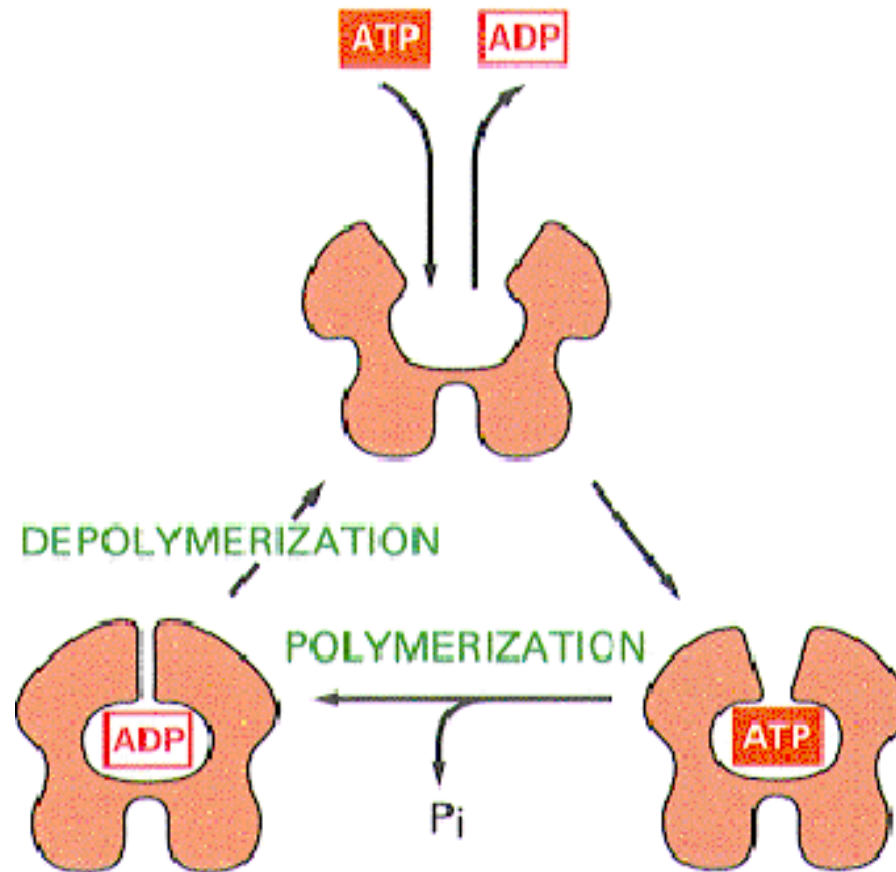


# Muskelfaser



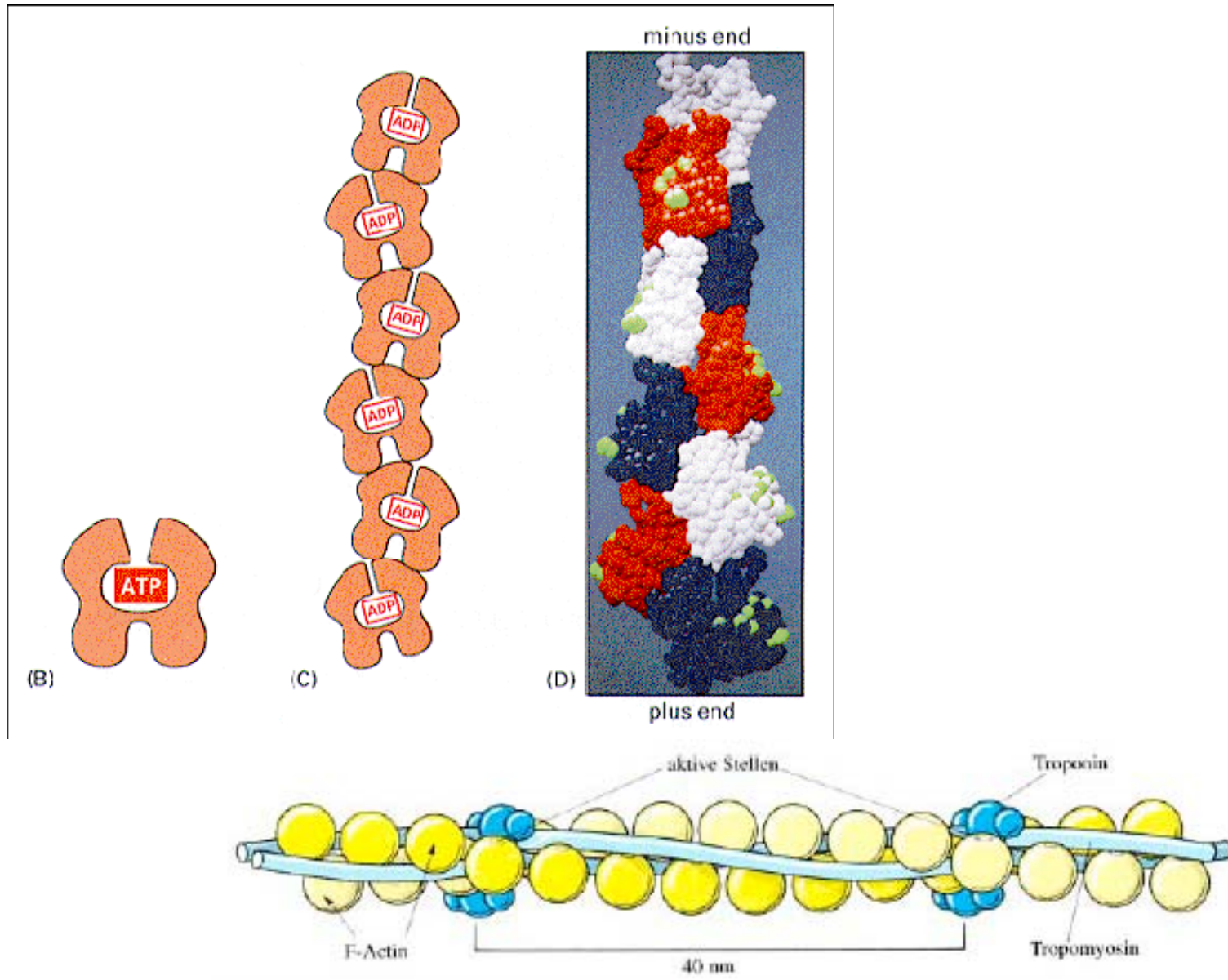
- a) Elektronenmikroskopische Aufnahme der gestreiften Muskulatur. Die hellen Bereiche bestehen aus dünnen Filamenten (Aktin) und werden als I-Band bezeichnet. In den dunklen Bereichen (A-Band) finden sich hauptsächlich dicke Filamente (Myosin)
- b) Schematische Zeichnung eines Sarkomers. Ein einzelnes Titinmolekül überspannt den Bereich von der Z-Scheibe zur M-Linie, wobei es im A-Band fest an die dicken Filamente gebunden ist.

# Aktin

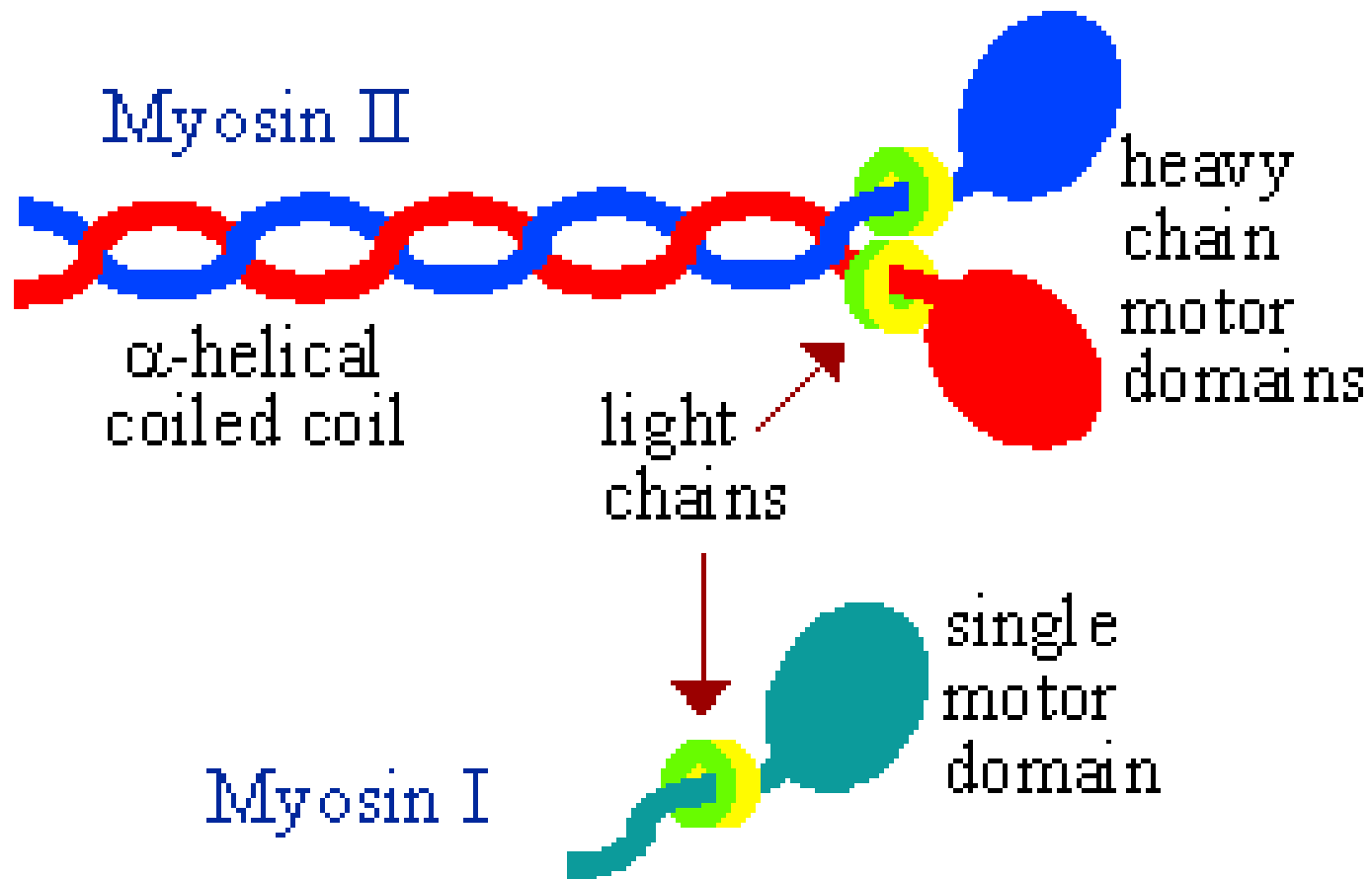




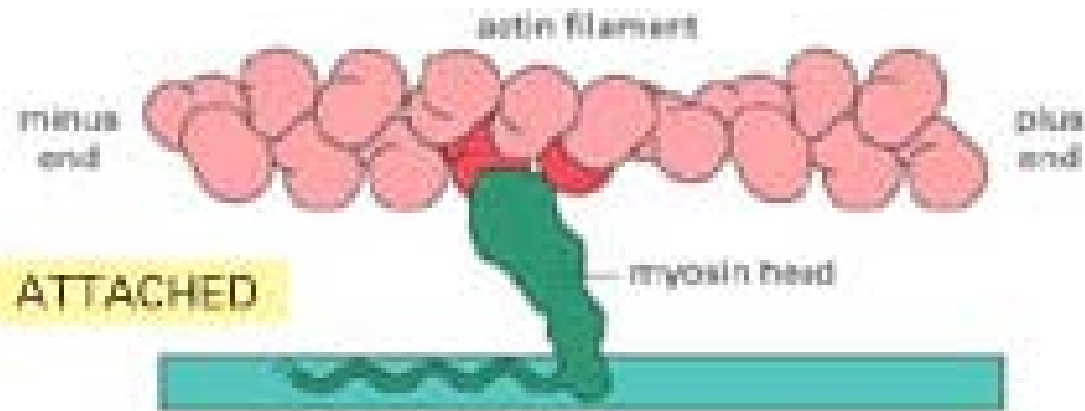
# Polymerisation Aktin



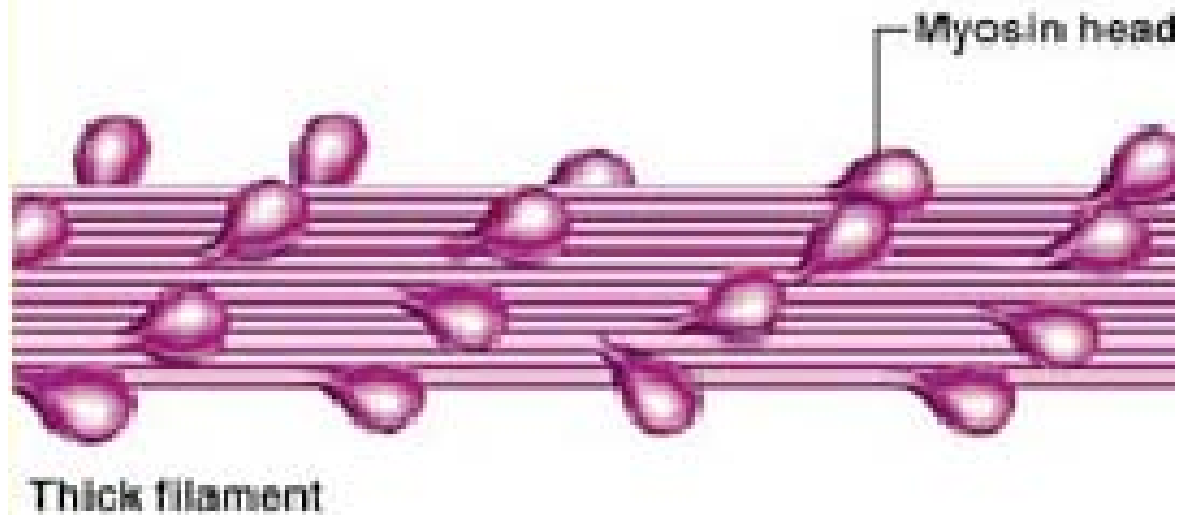
# Myosin



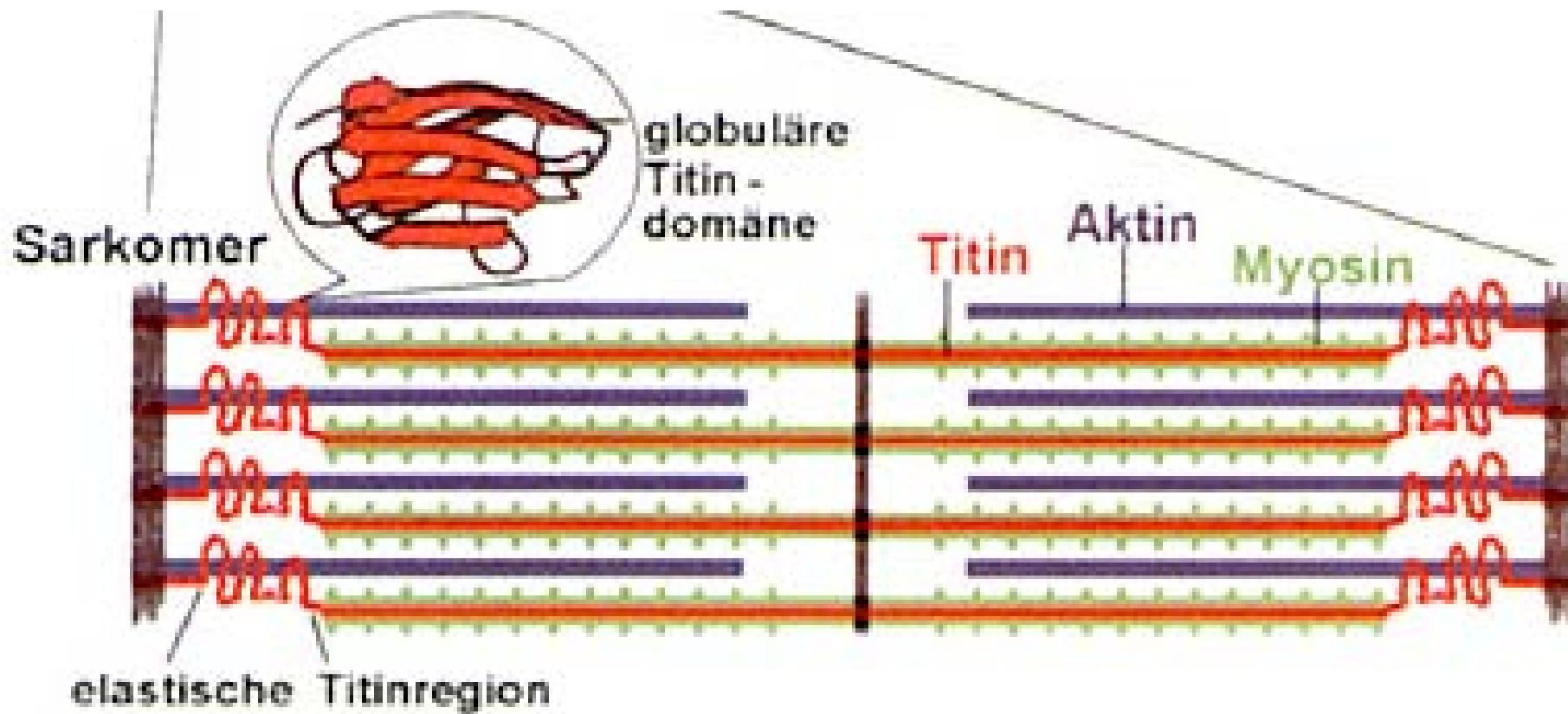
# Myosinfilament



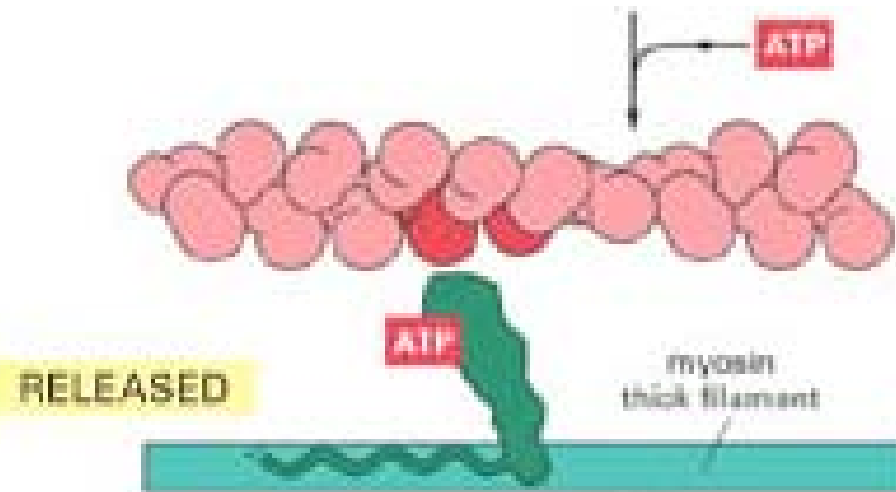
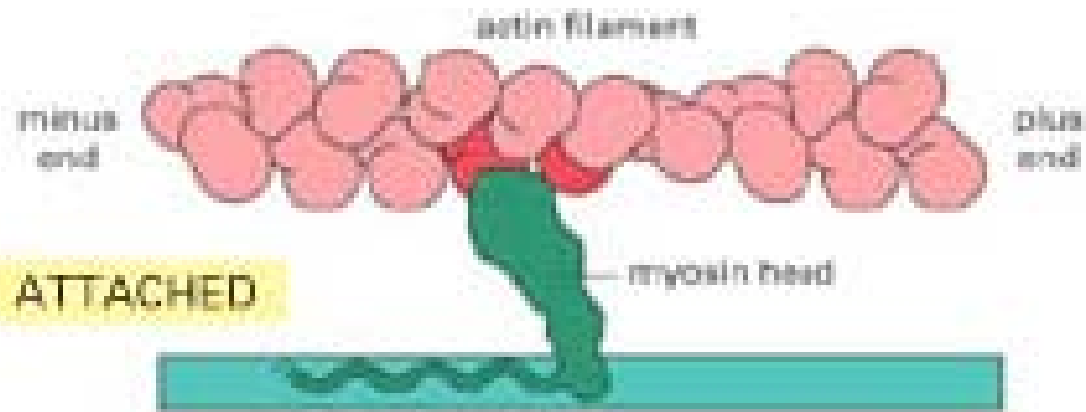
## Structure of Myofilaments (2)



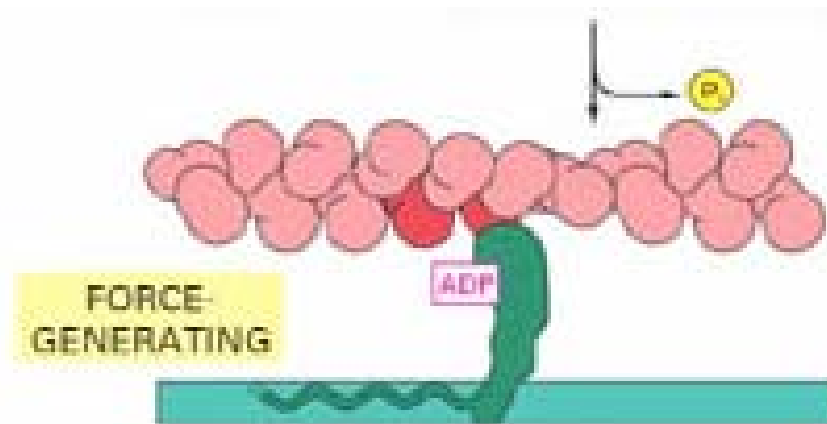
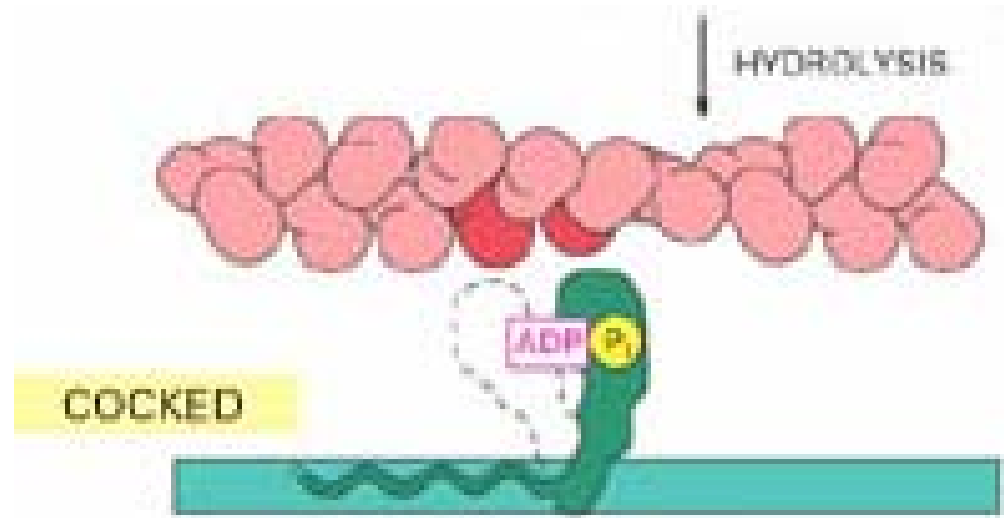
# Titin - Stabilisator

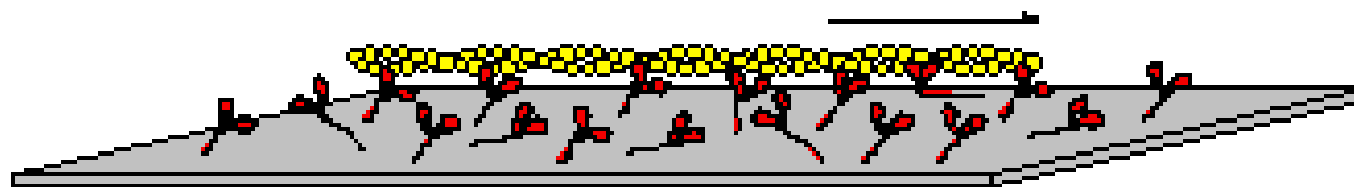
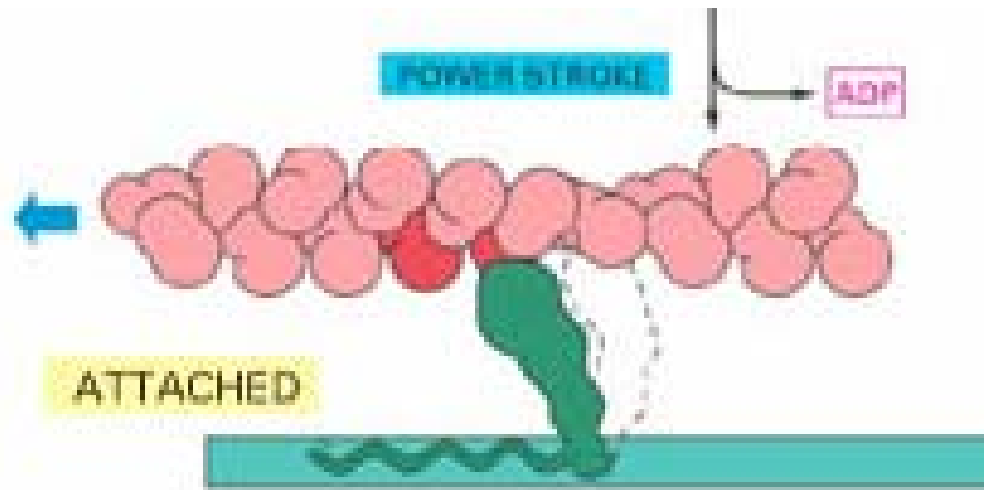


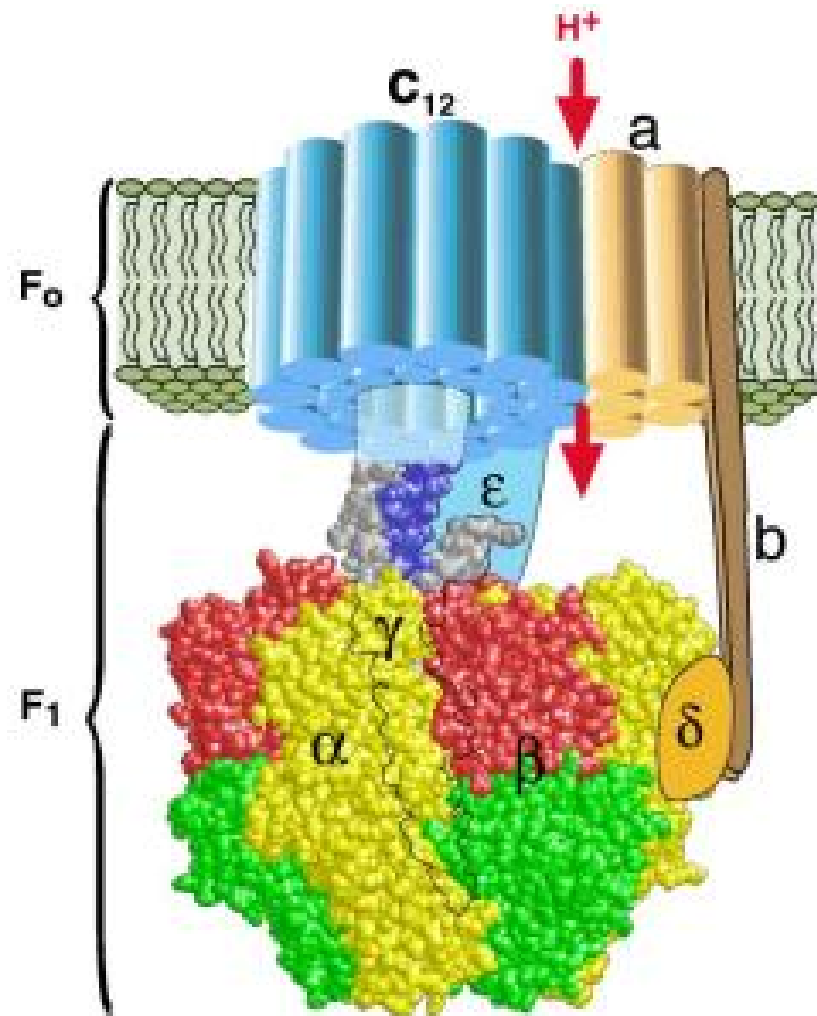
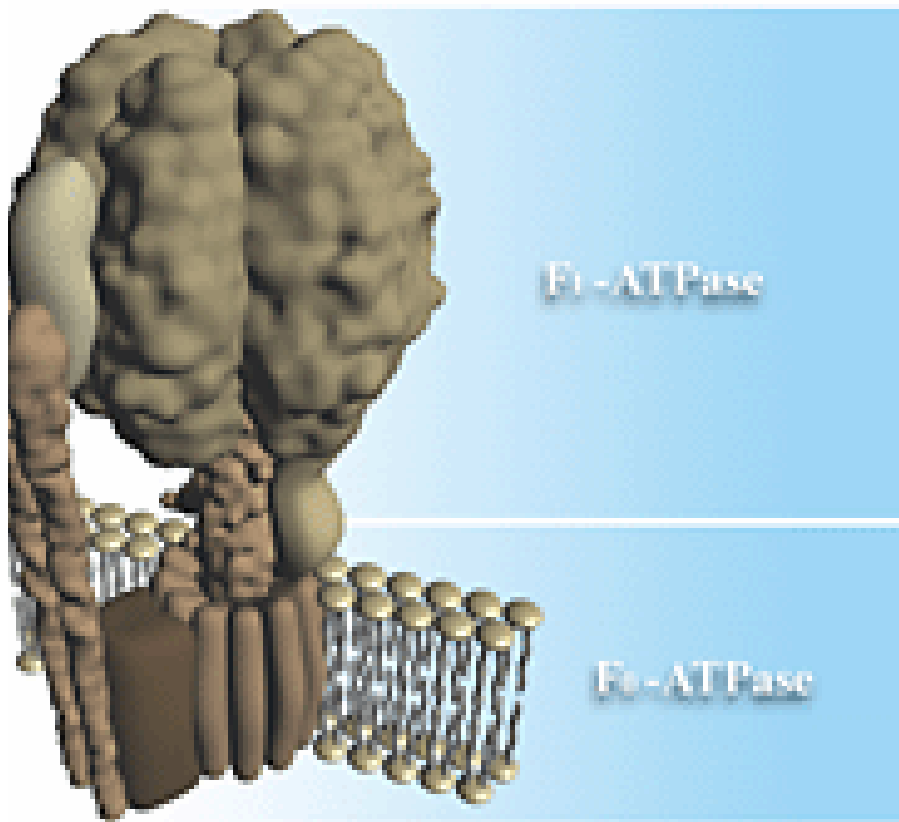
# ATP – Einfluß I



# ATP – Einfluß II

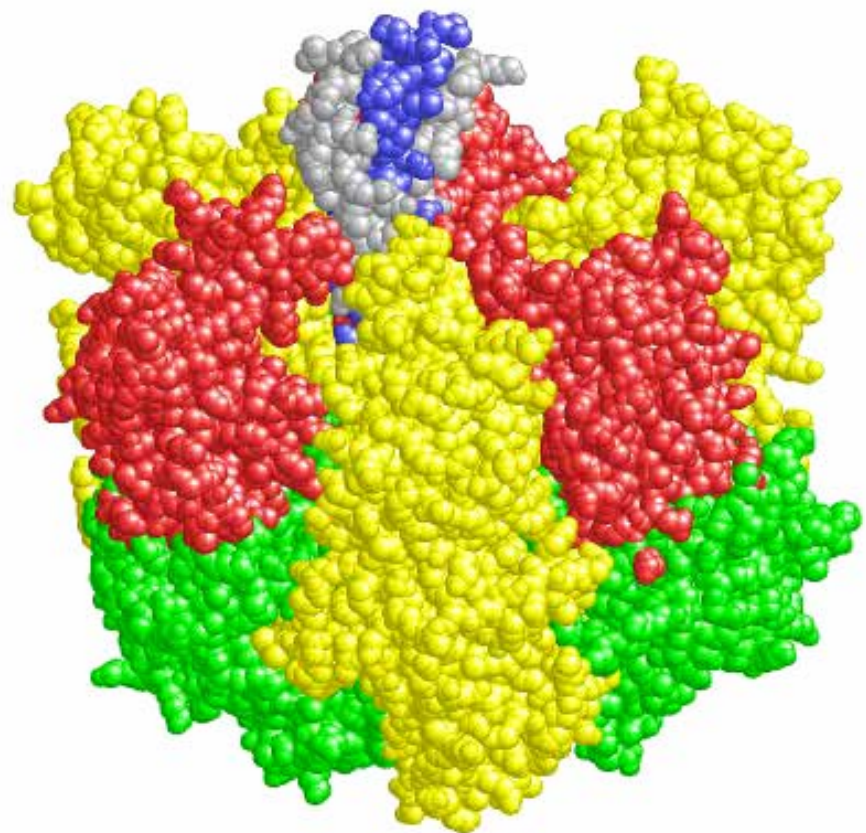


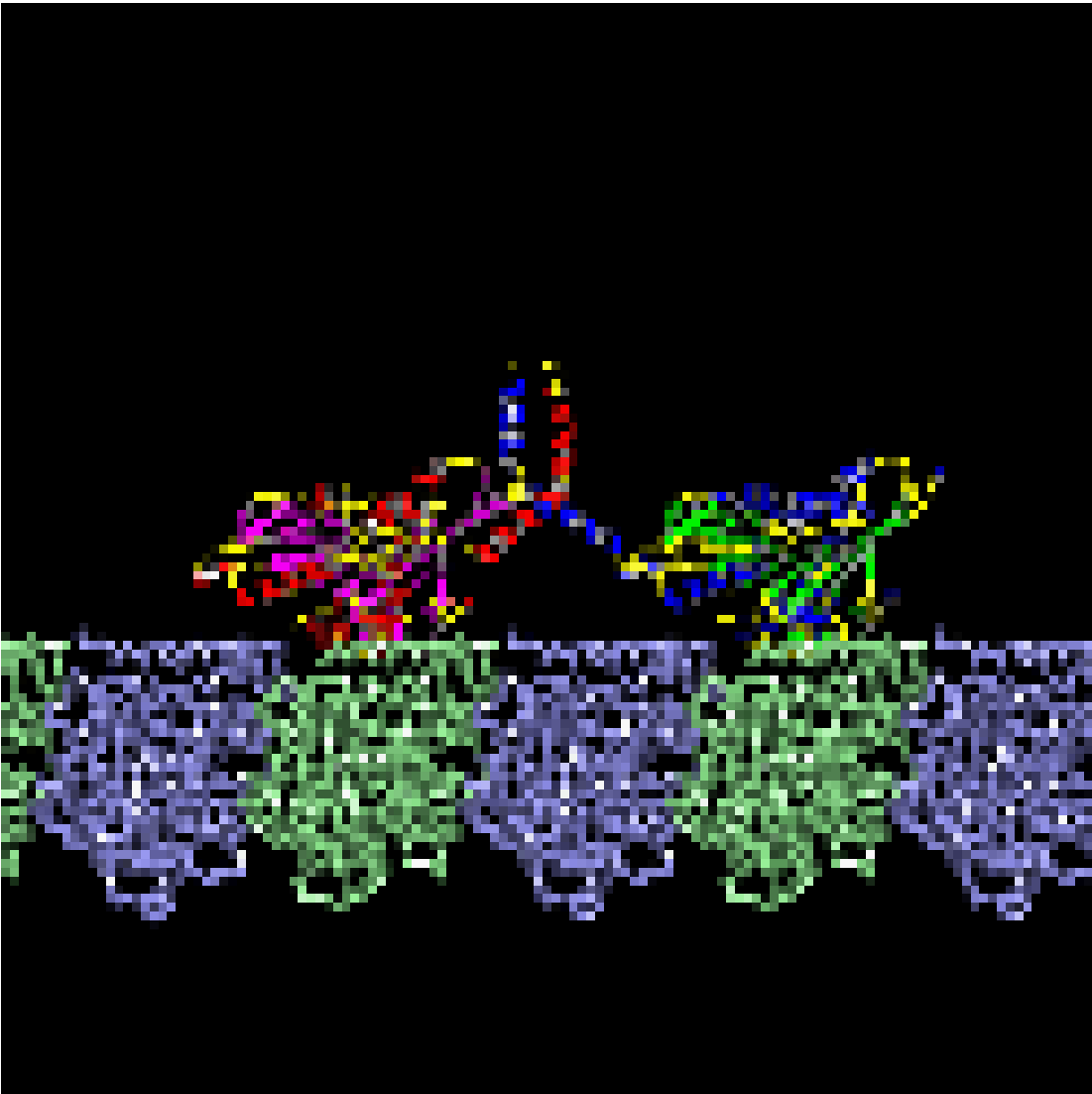


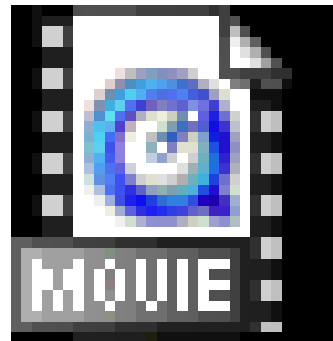


H. Wang and G. Oster (1998). Nature 396:279-282.



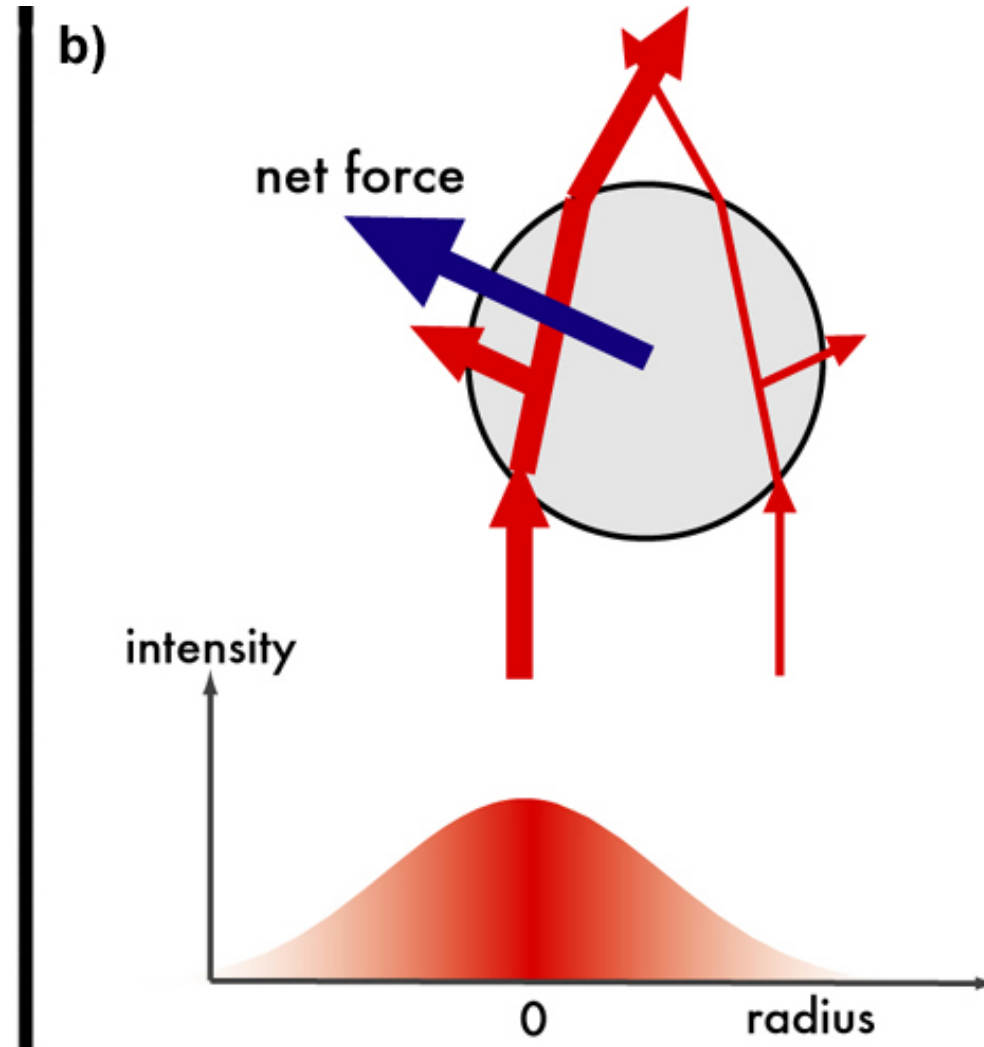
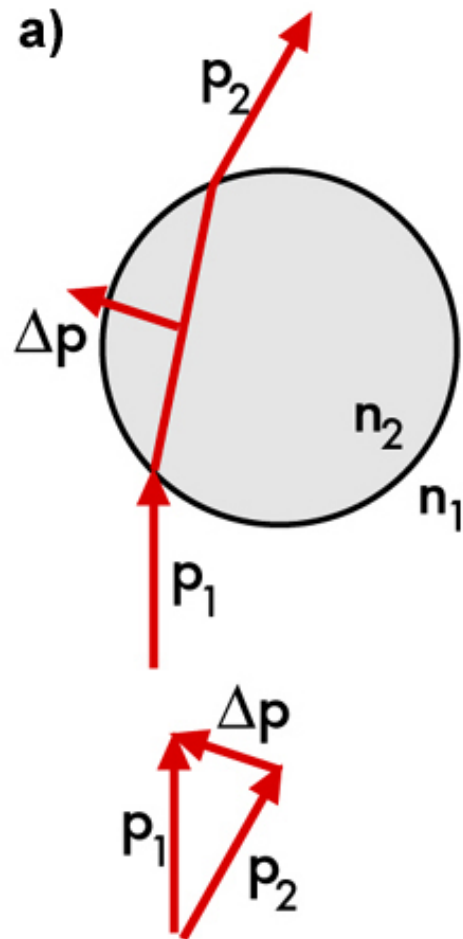




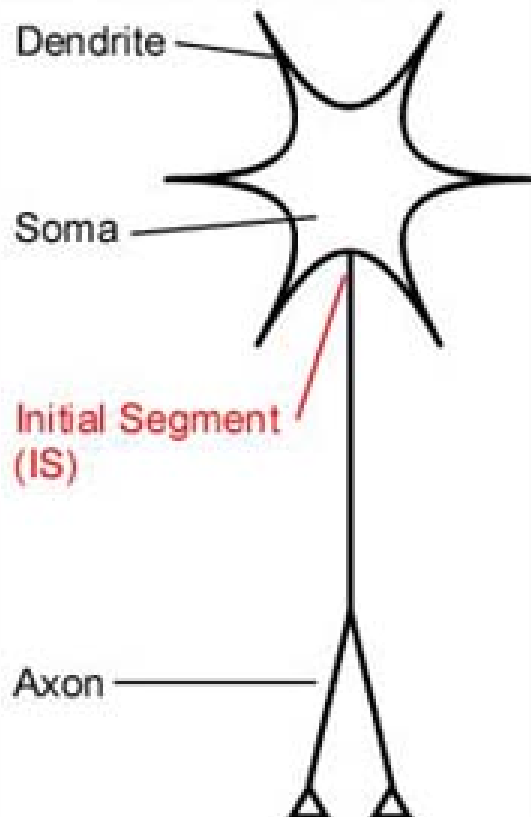


myosin\_muscle\_animation.mov

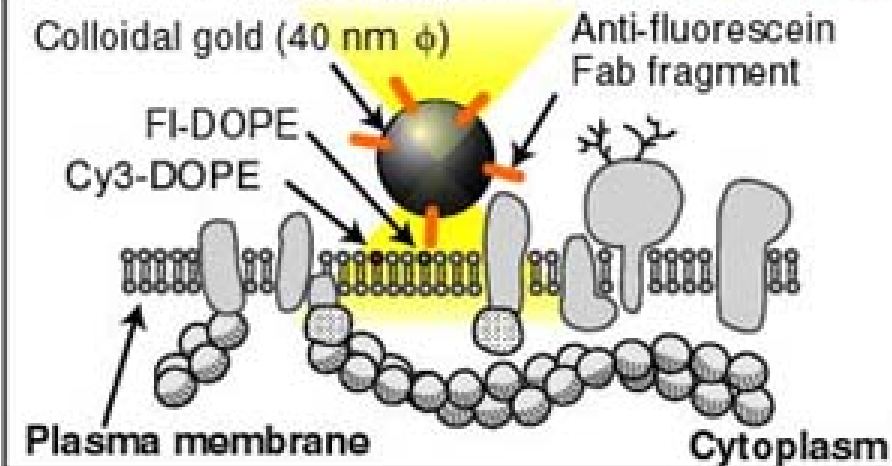
# Optische Pinzette



## New-Born Rat Hippocampal Culture



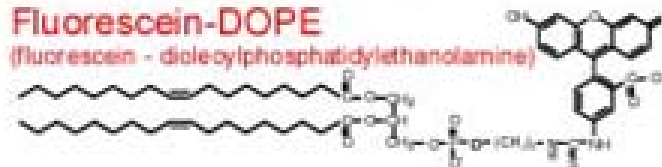
## Single Particle Tracking/ Optical Tweezers



## Phospholipid Probe

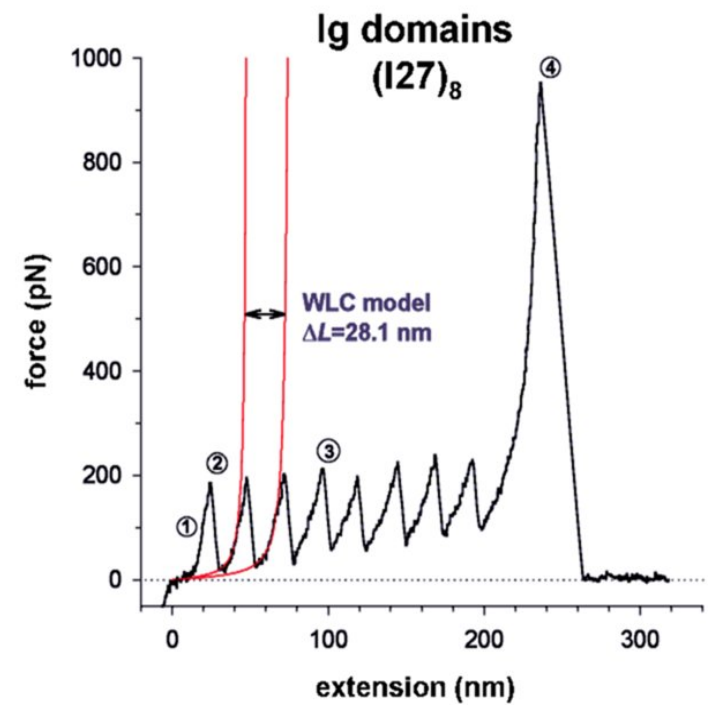
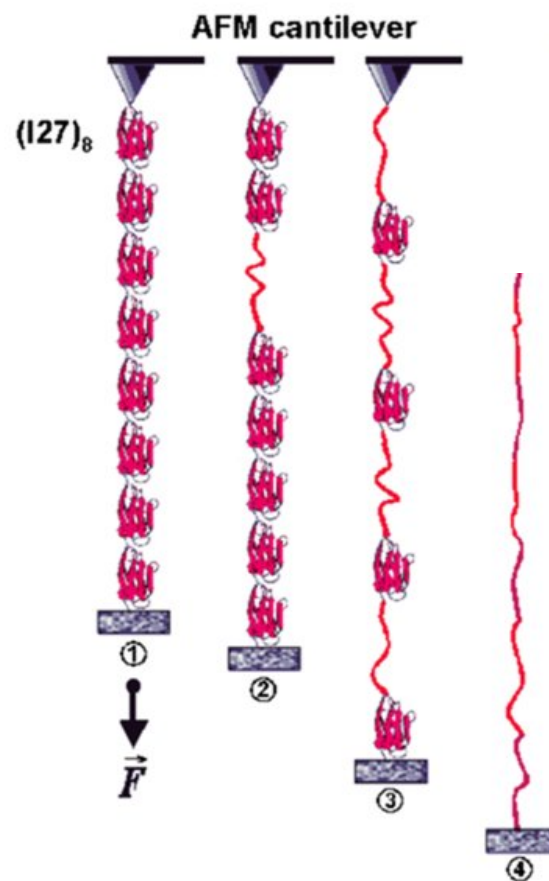
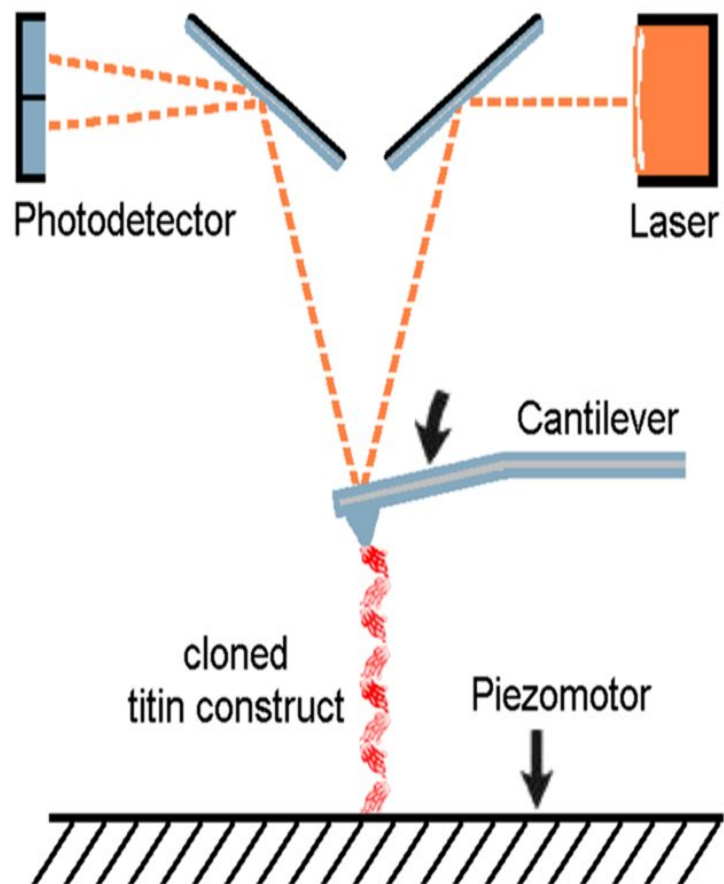
### Fluorescein-DOPE

(fluorescein - dioleoylphosphatidylethanolamine)

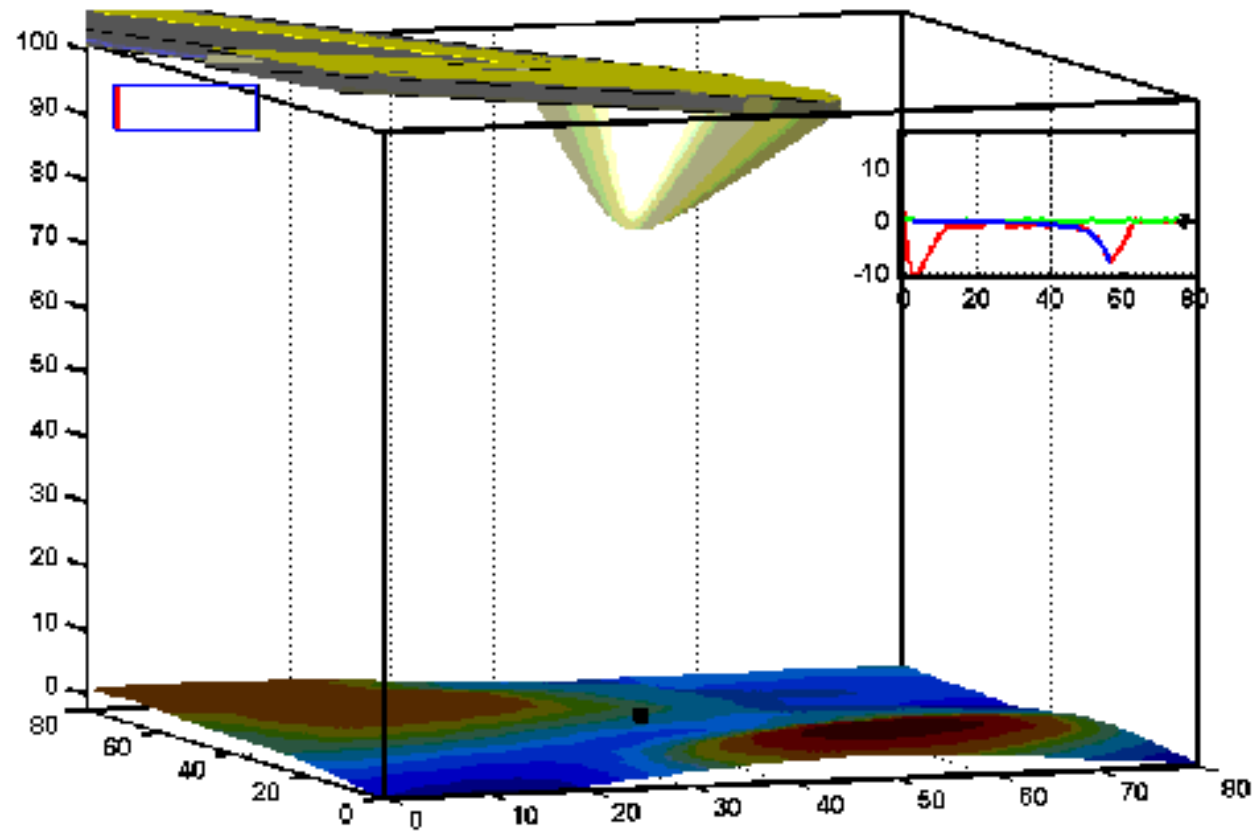


### Cy3-DOPE

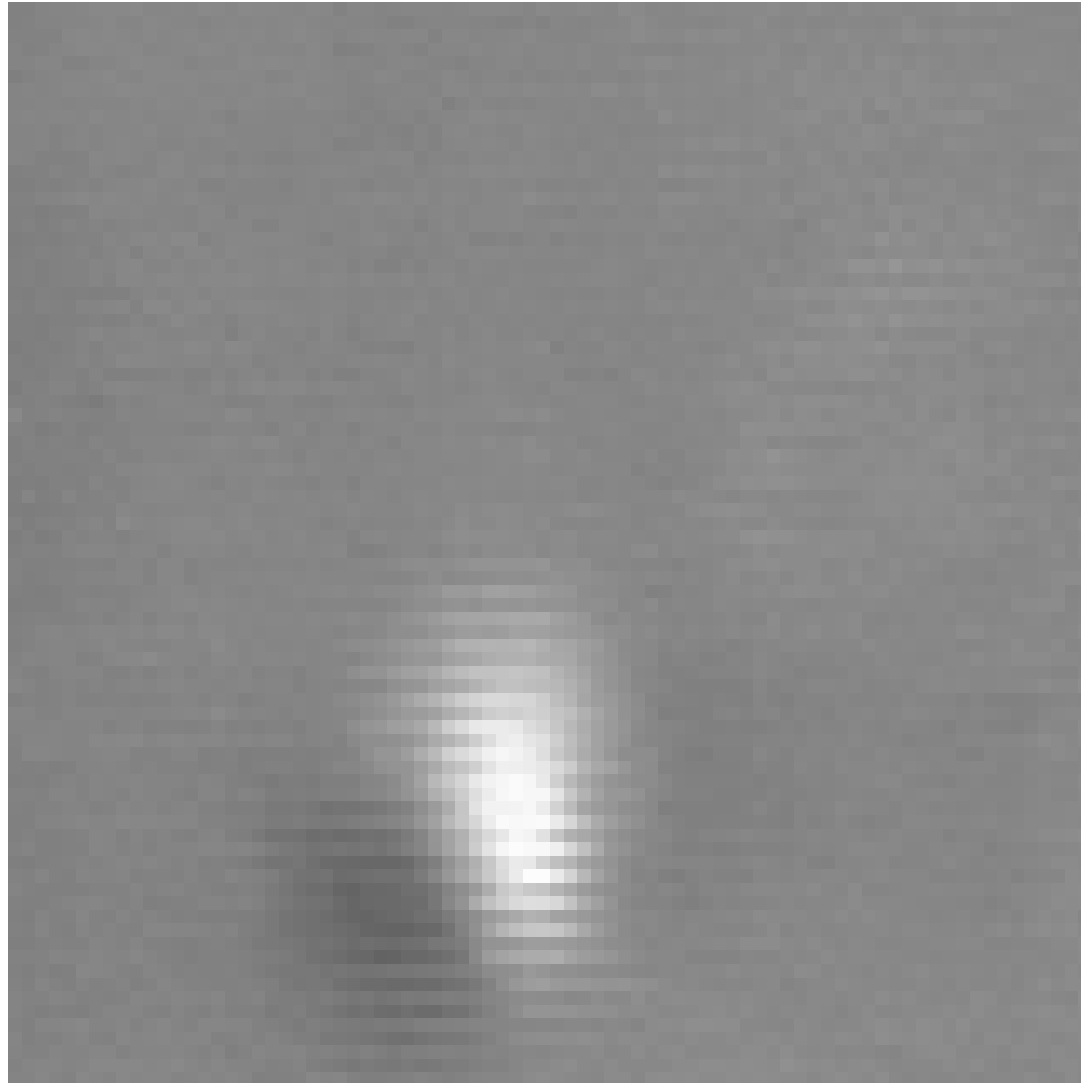




# AFM

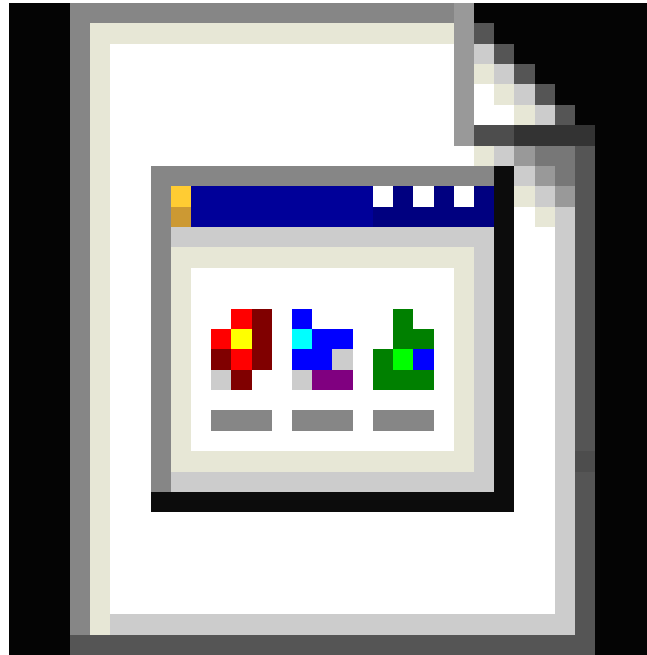


# Fixierung mit optischer Pinzette

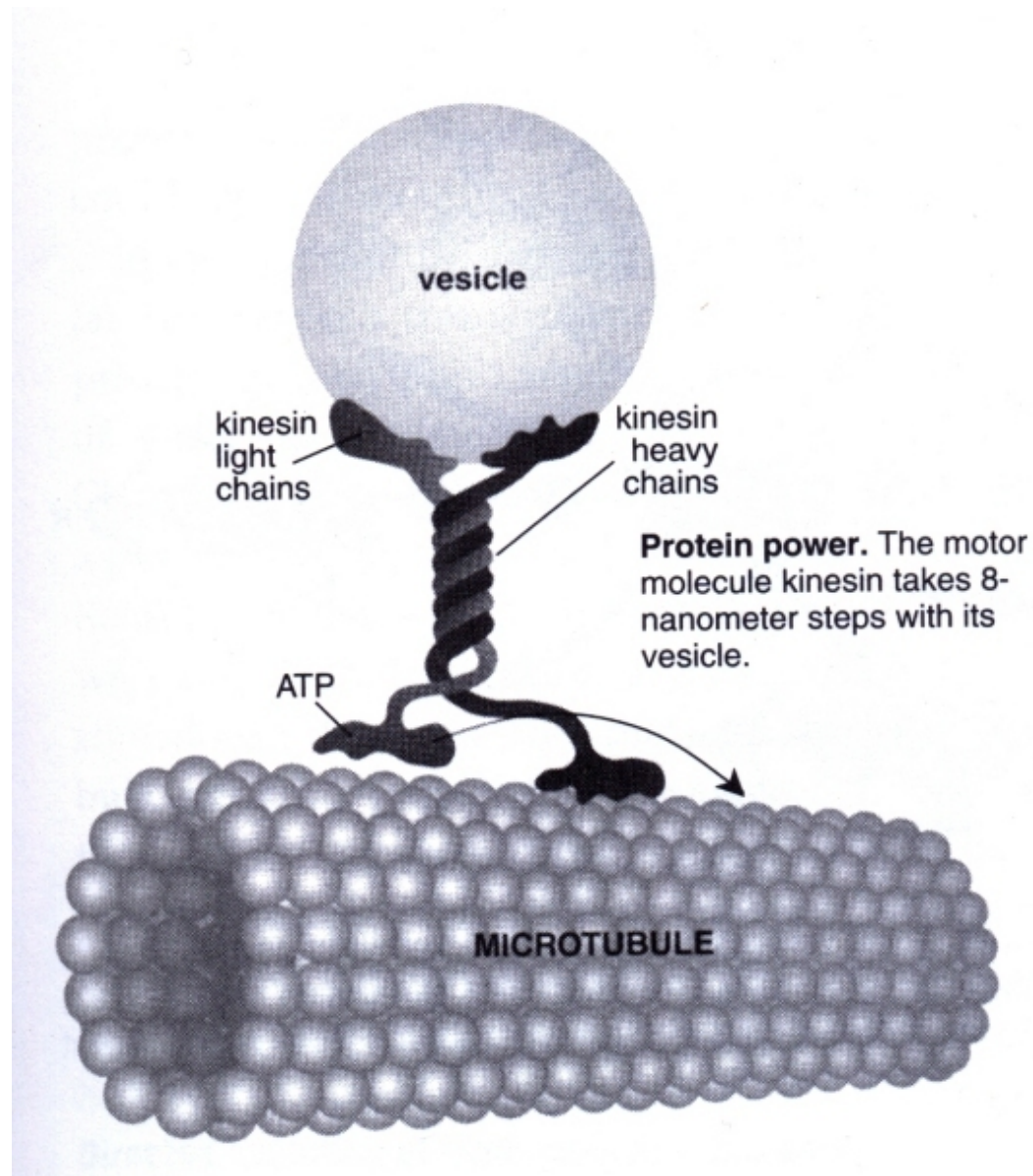




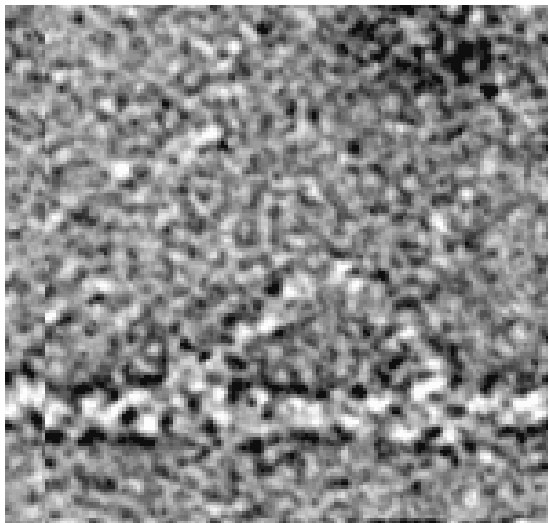
# Optische Pinzette - Strecken



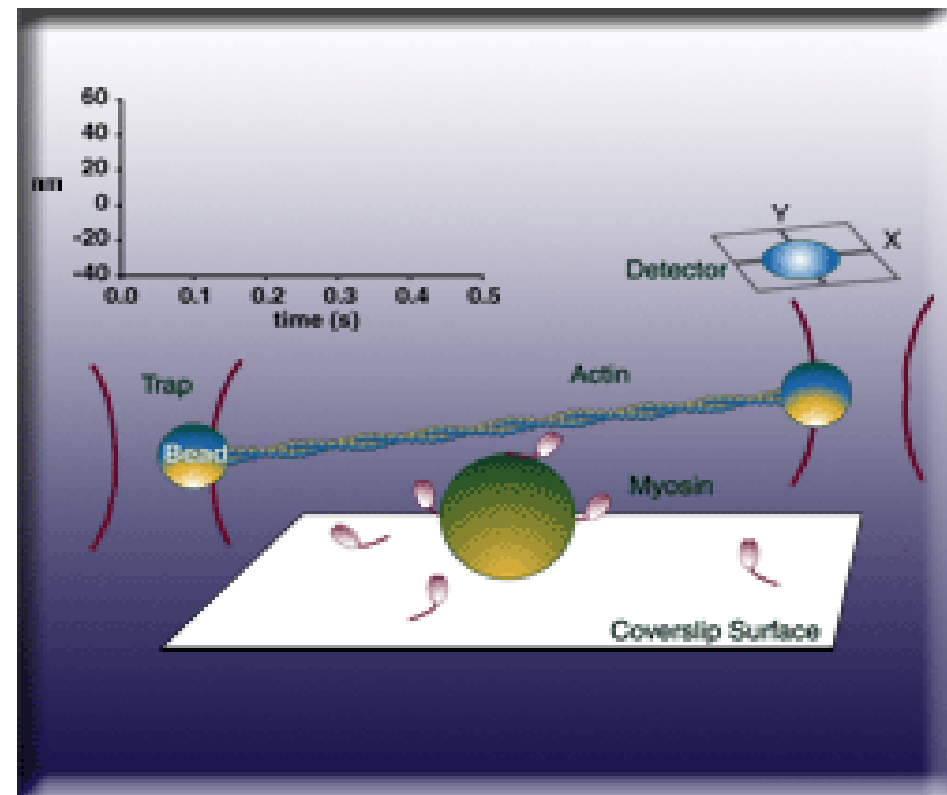
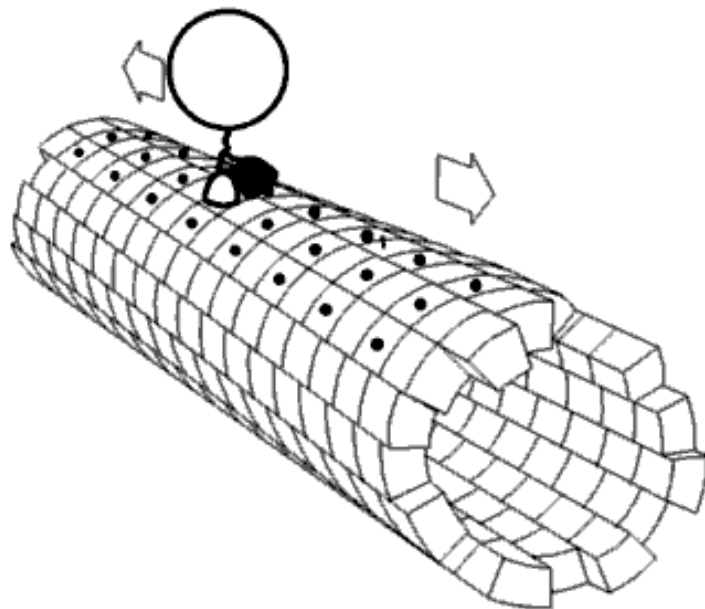
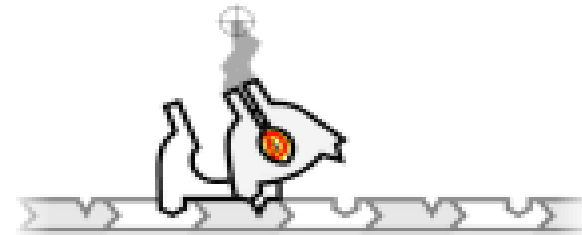
tweezer2.mov



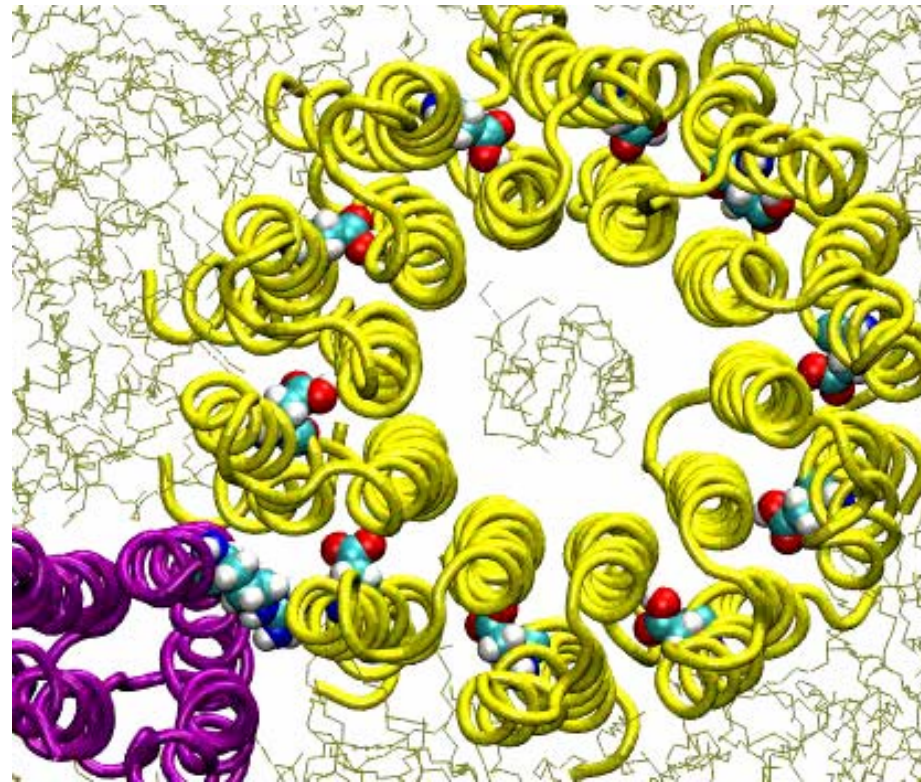
# Nanometer - Motoren

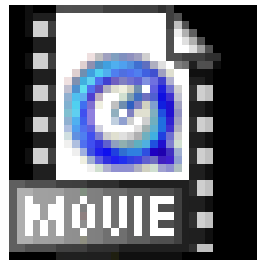


The Muscle Group, Leeds 2000

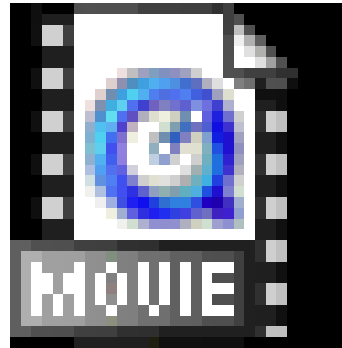


# Molekulardynamische Simulation





kinesin\_procession\_animation.mov



Noji\_ATPase\_rotating\_film.mov