

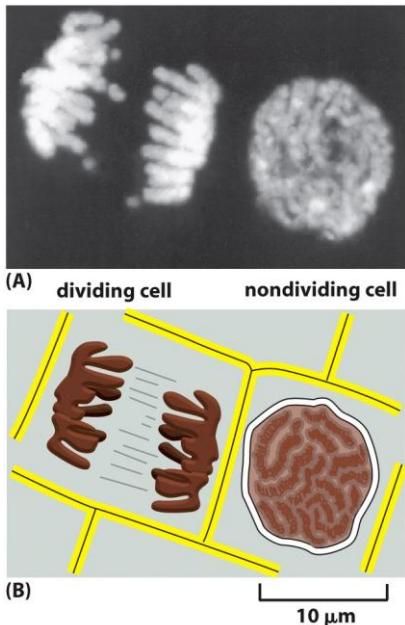
DNA, Molecular Machines and Subcellular Organization

April 26, 2019

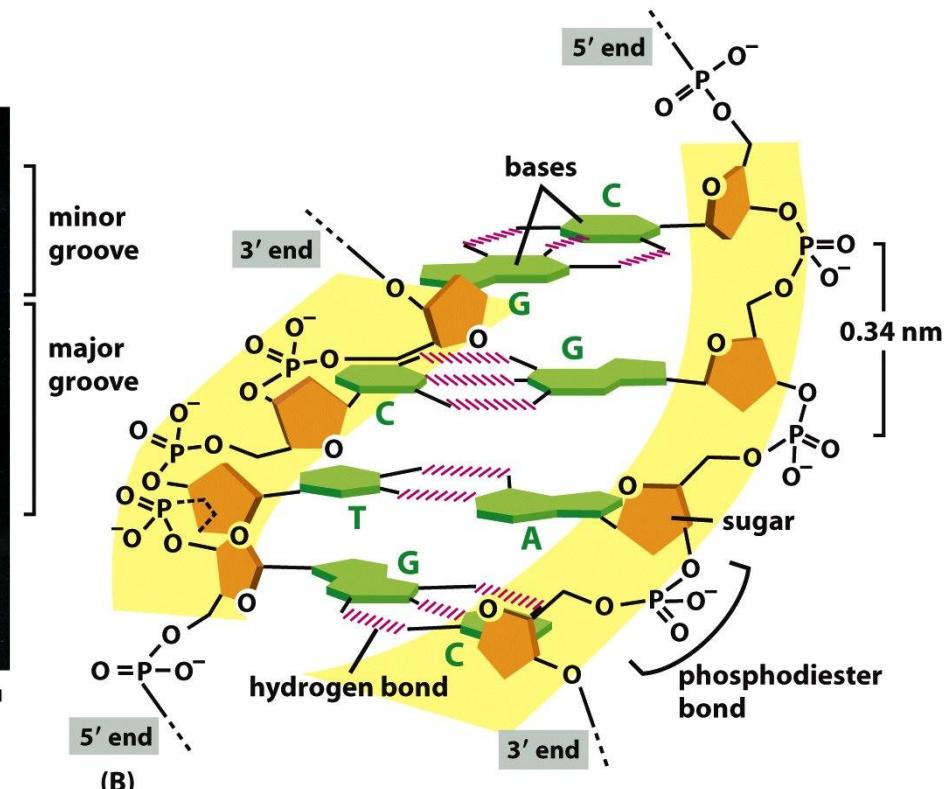
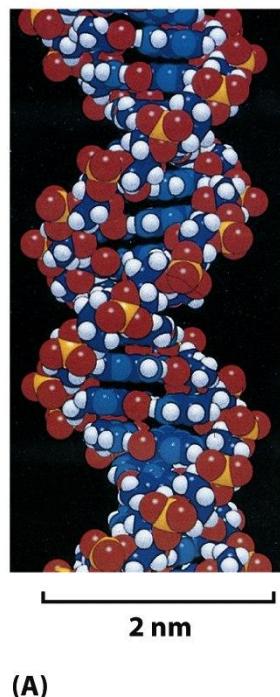
Dr. Annette Kraegeloh

INM - Leibniz Institute for New Materials

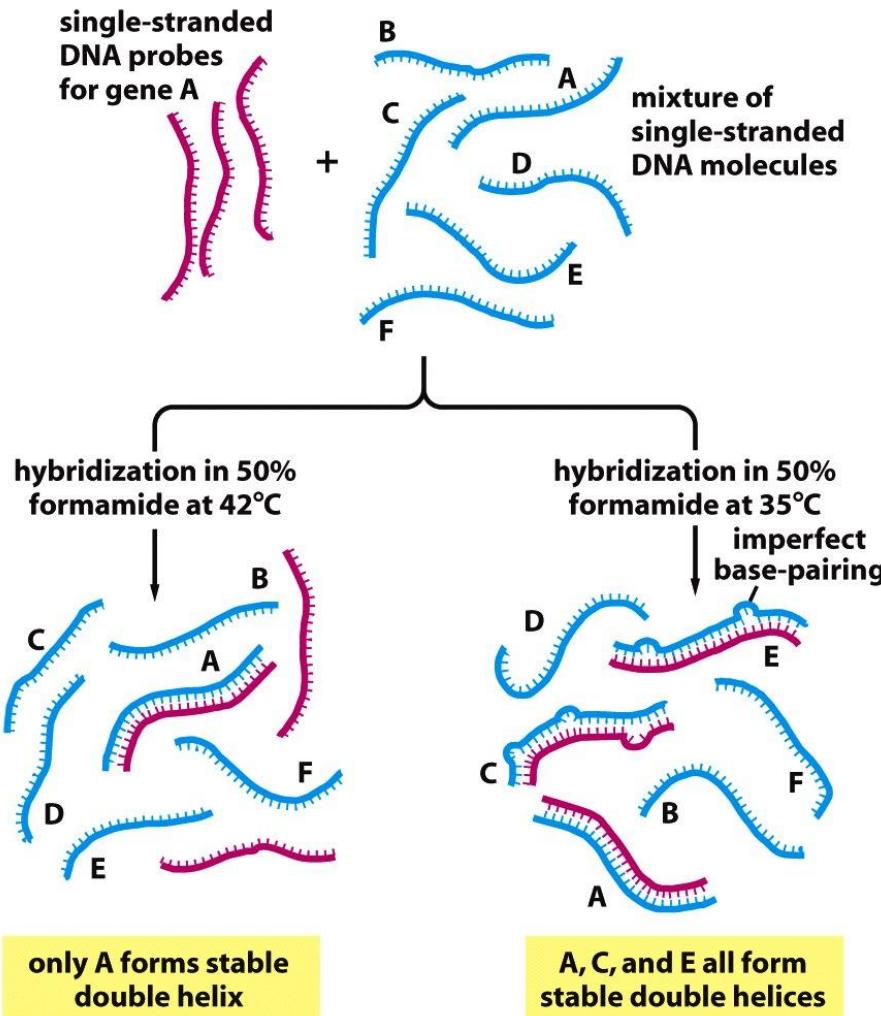
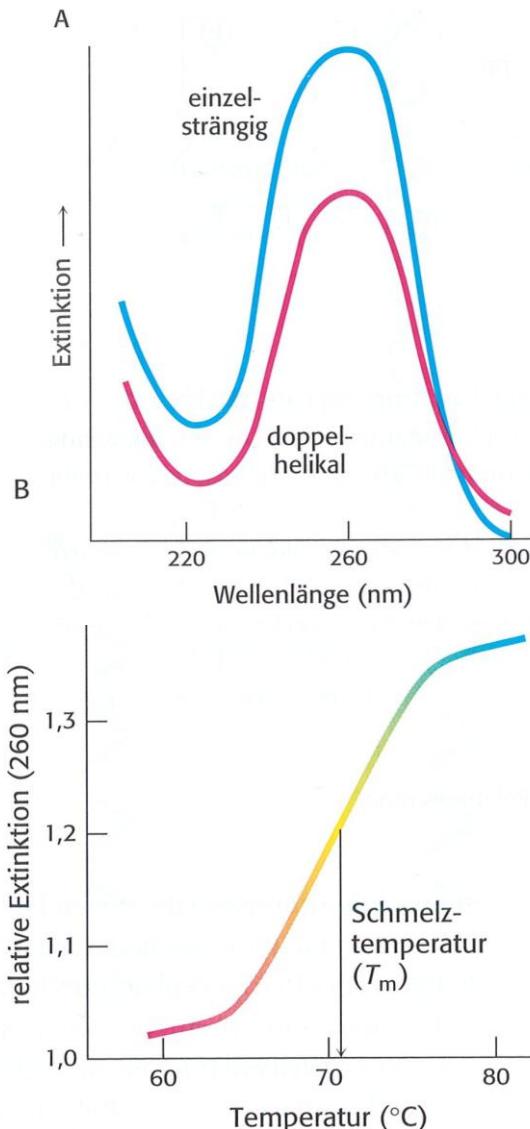
DNA Stores the Genetic Information of Cells



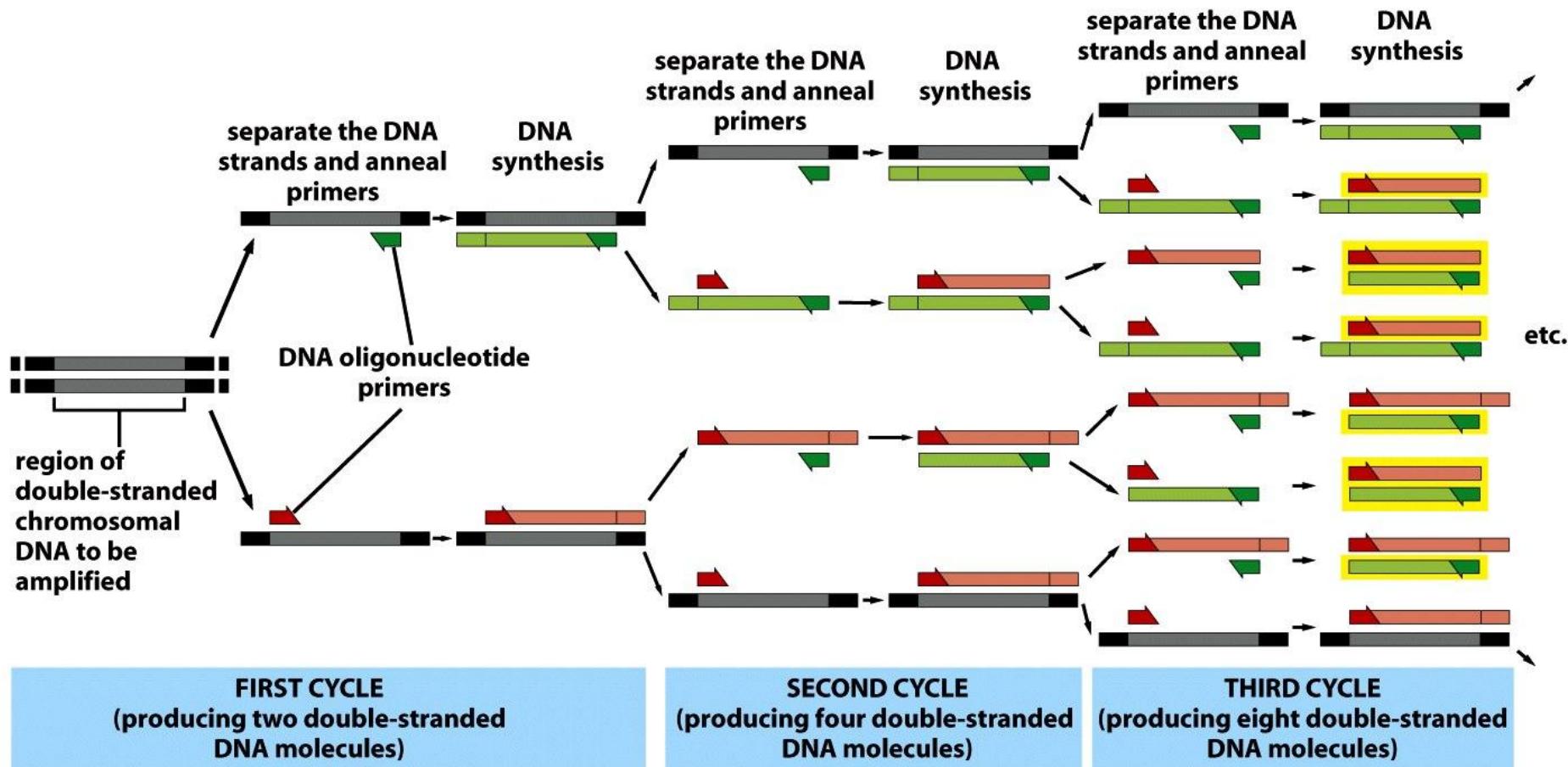
chromosomes in eukaryotic cells



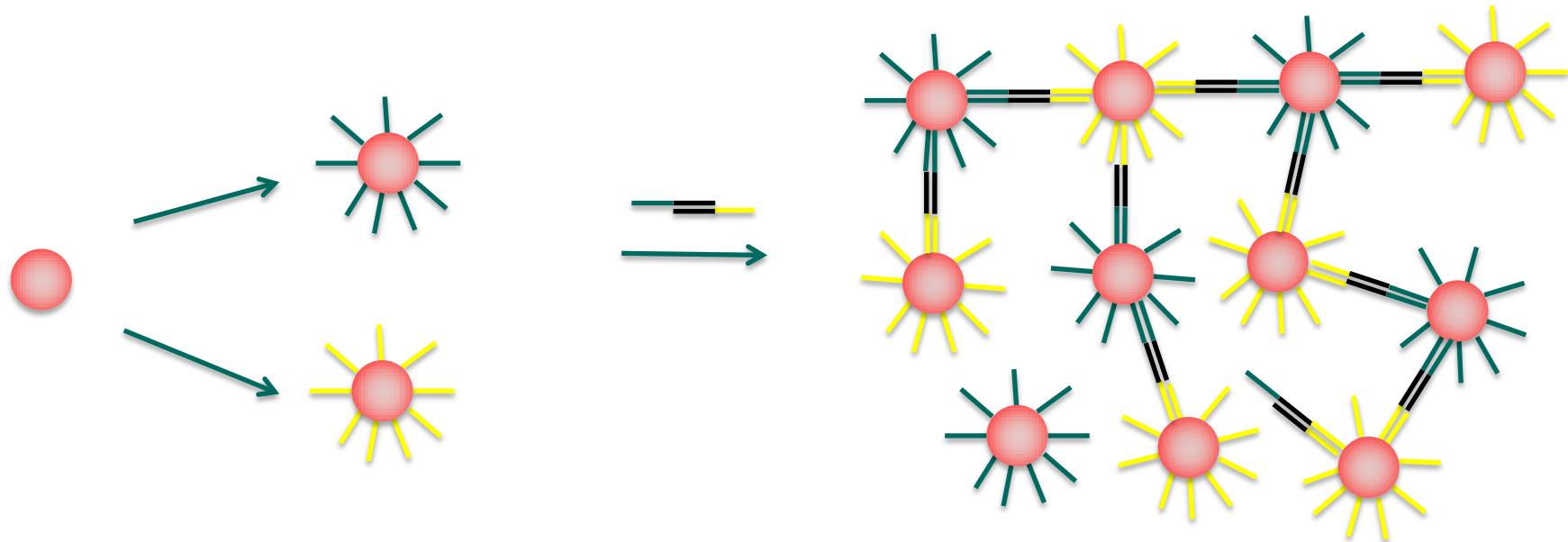
DNA Hybridization and Melting



Amplification of DNA by the PCR technique



DNA Based Assembly of Nanoparticles



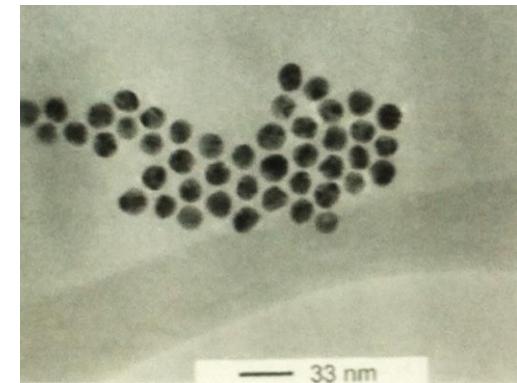
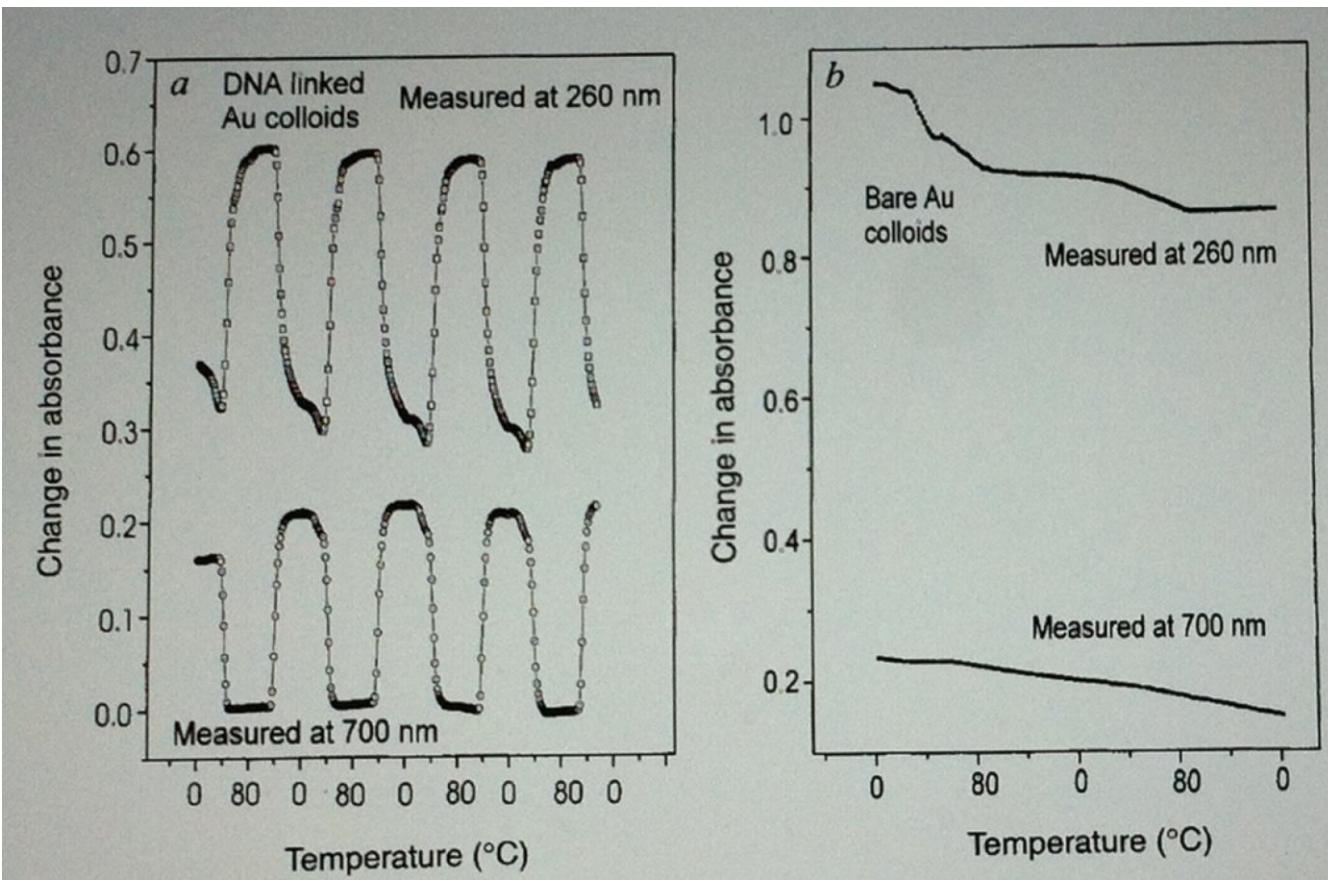
— 5'-GTTGCCAT-3'-thiol

— 5'-AGTCGTTT-3'-thiol

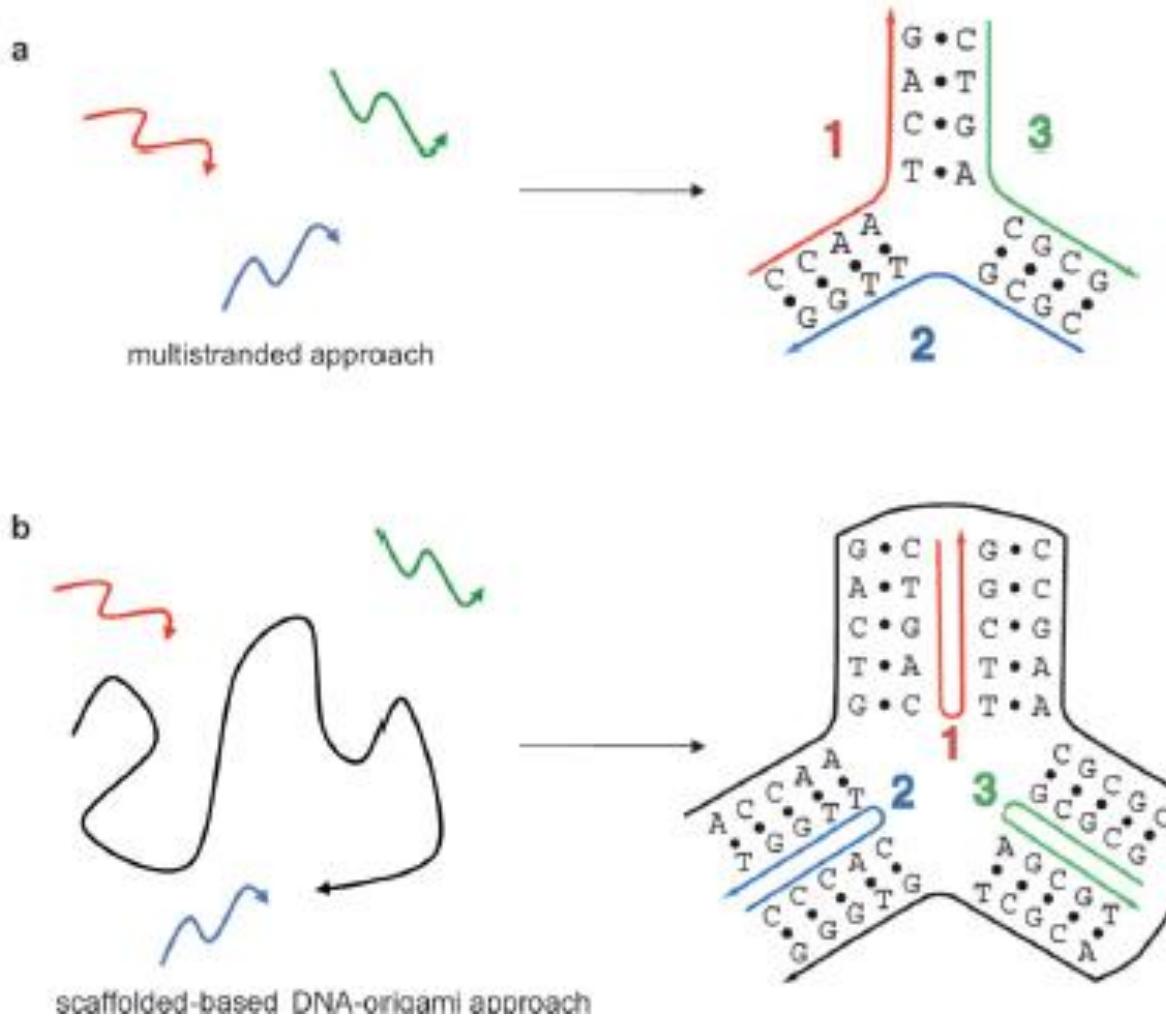
— 5'-ATGGCAAC-Box-
Box-TCAGCAAA-5'



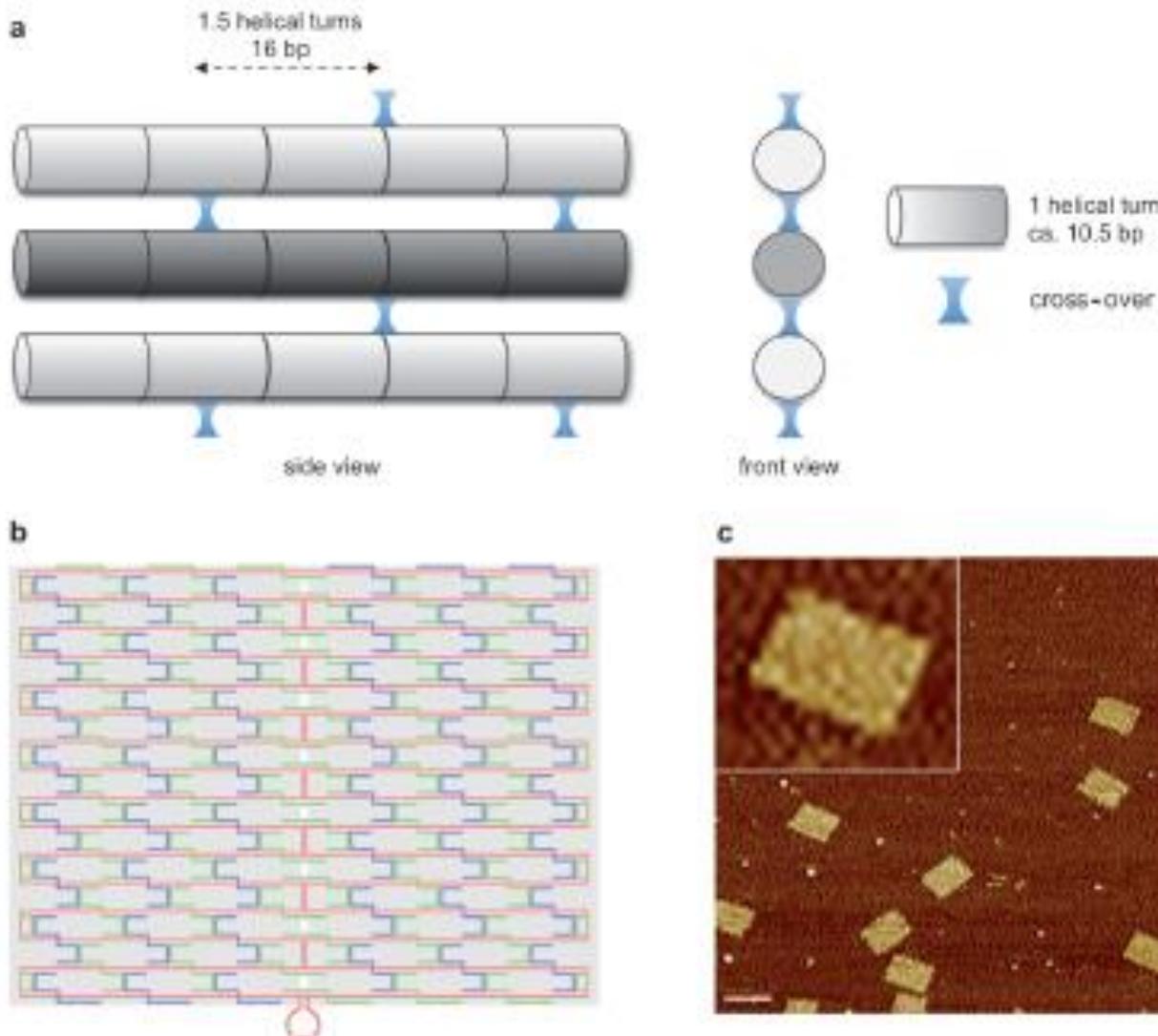
DNA Based Assembly of Nanoparticles



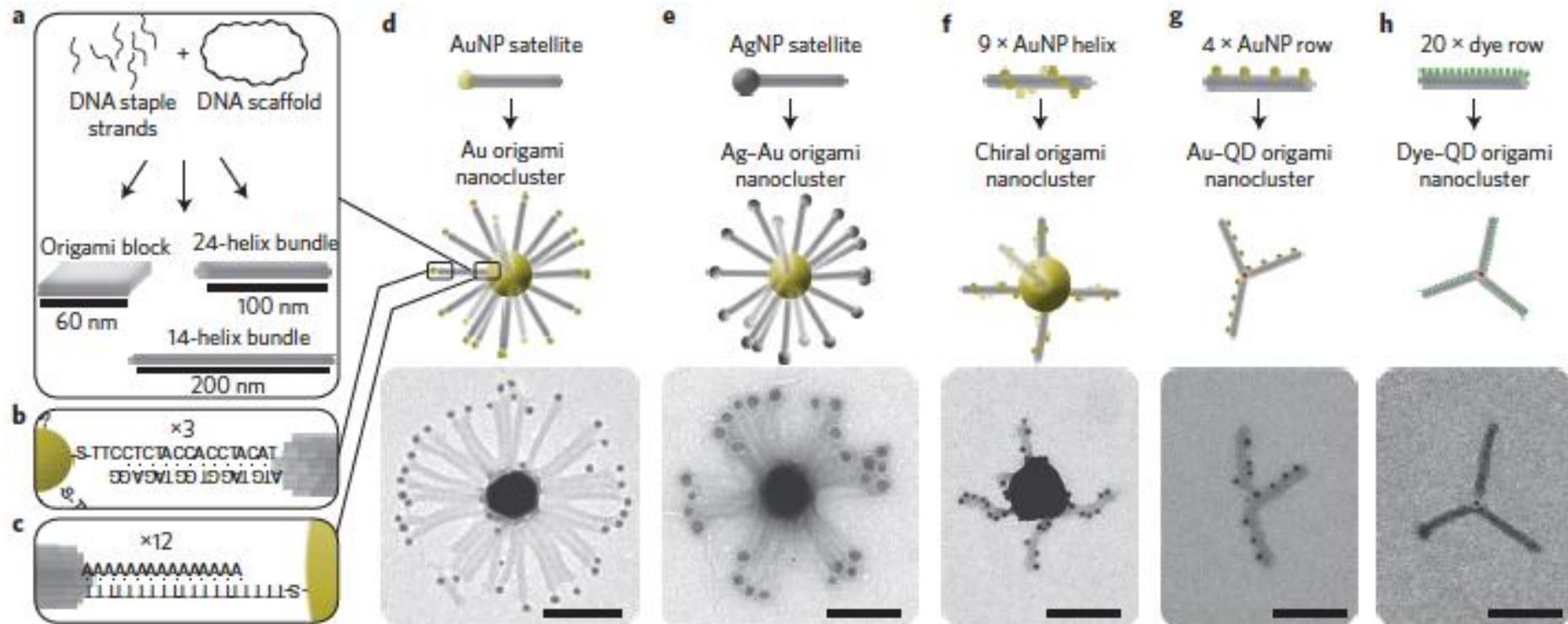
Construction of DNA Based Architectures



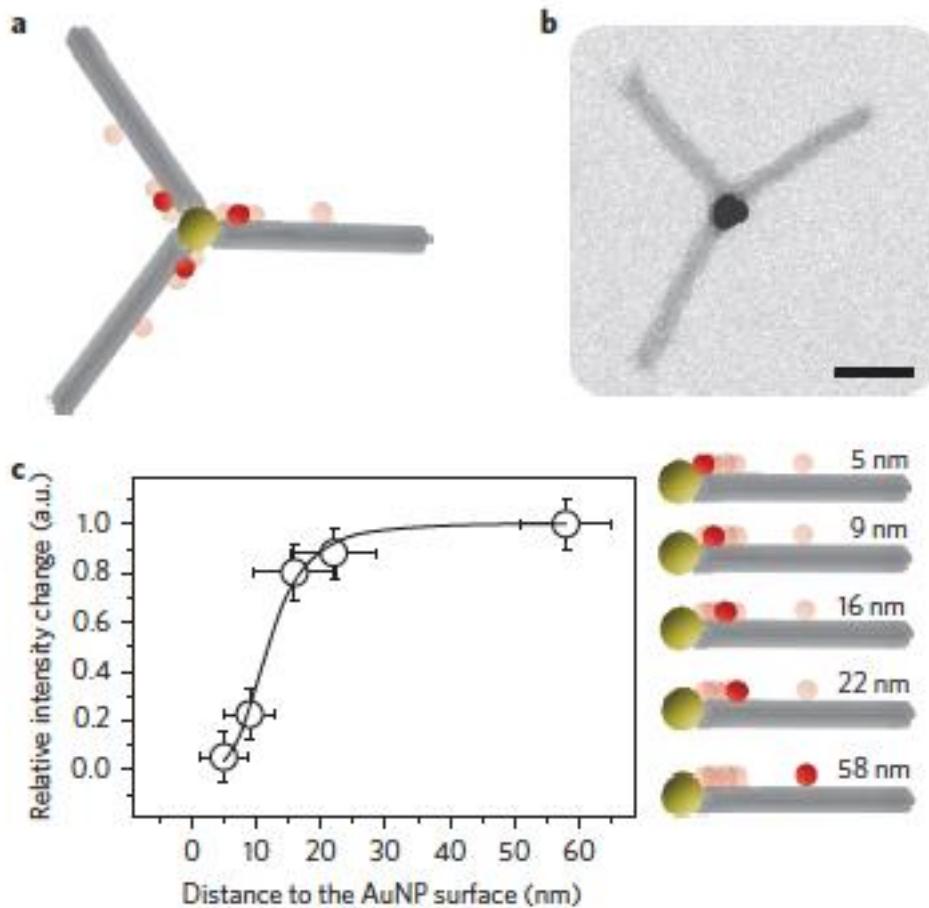
Design of 2D DNA Origami



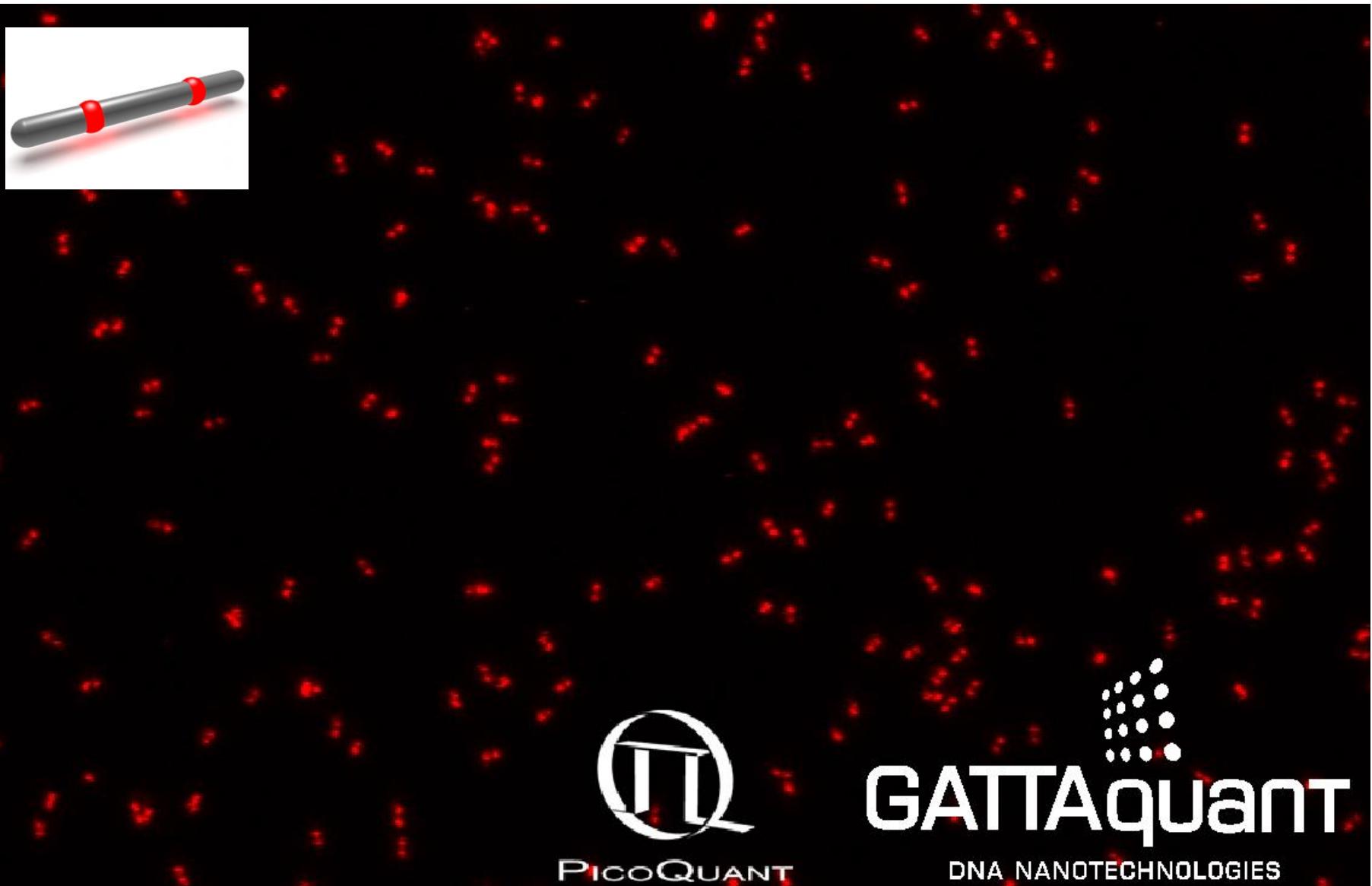
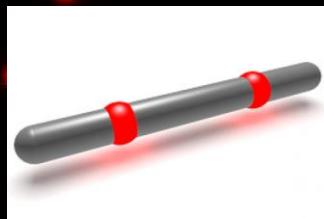
Hierarchical Planet Satellite Origami Nanoclusters



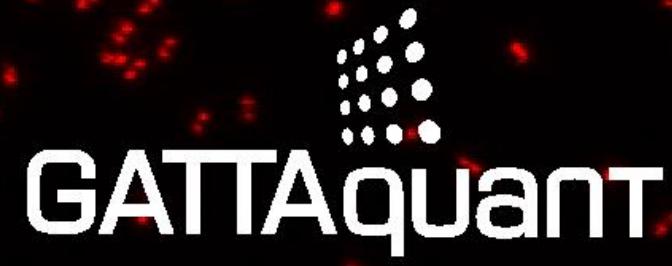
Photofunctional Origami Nanoclusters



DNA Origami Based Microscopy Rulers



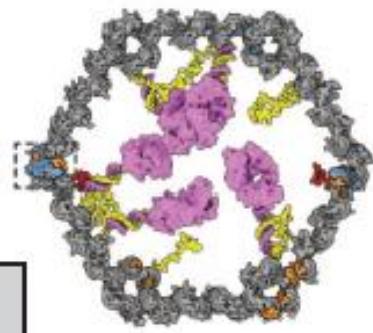
PicoQuant



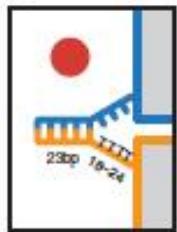
DNA NANOTECHNOLOGIES

DNA Nanorobot for Molecule Delivery

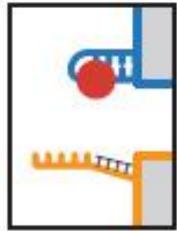
A



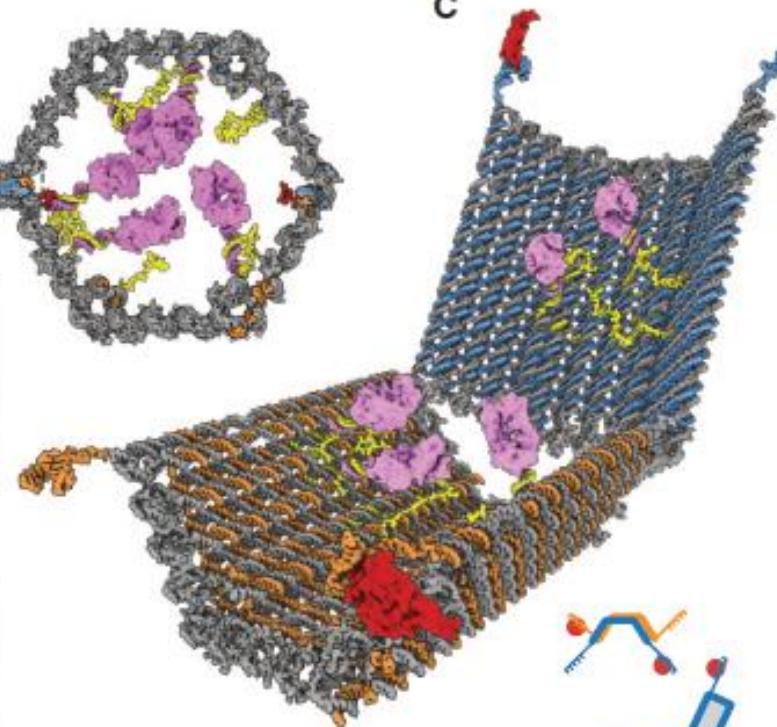
B



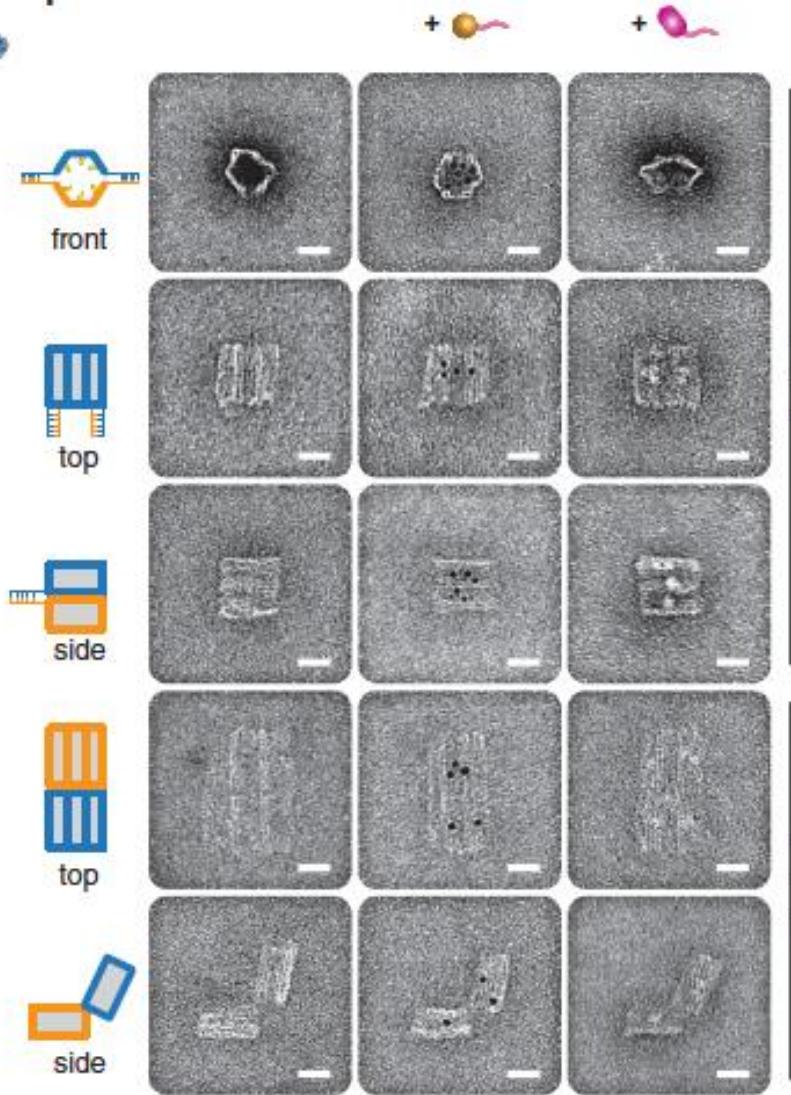
11



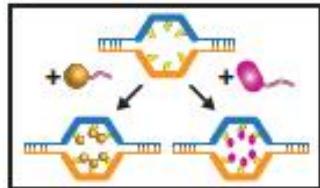
C



F



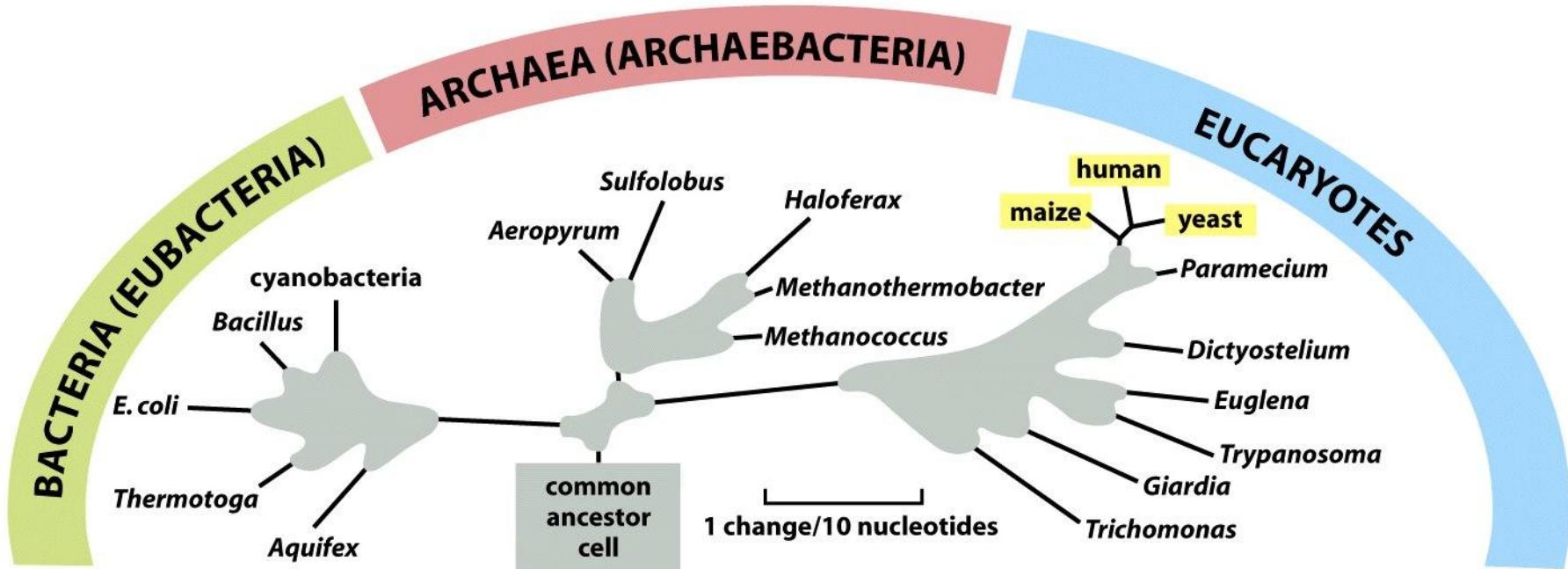
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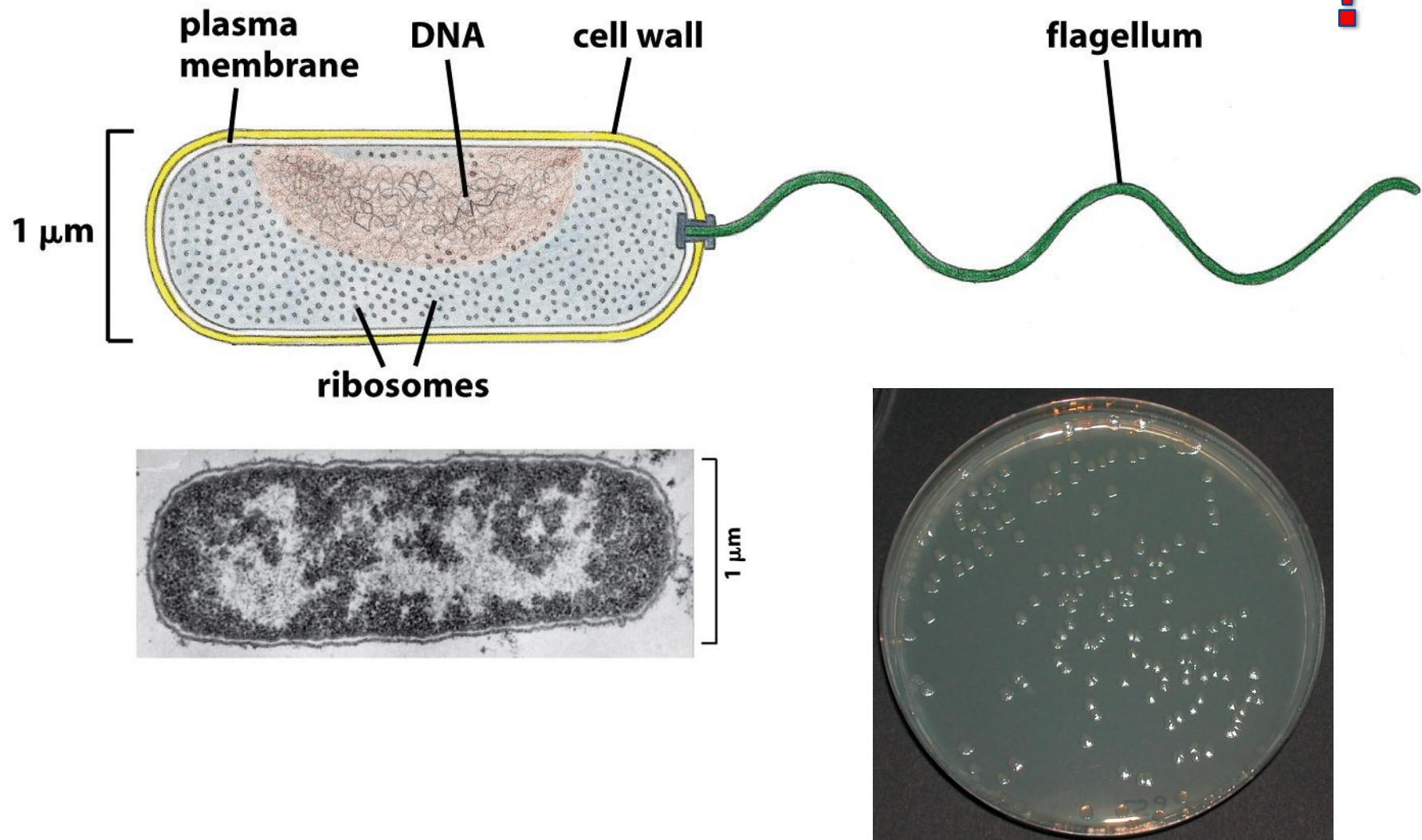
E



Domains of the Living World

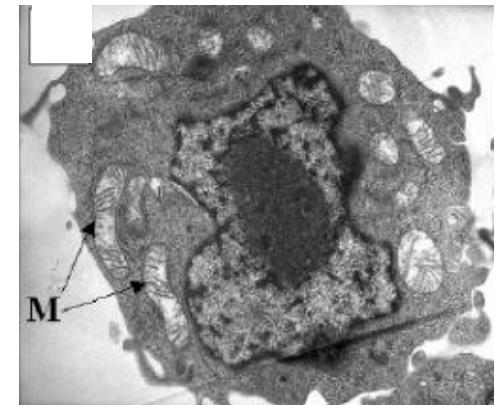
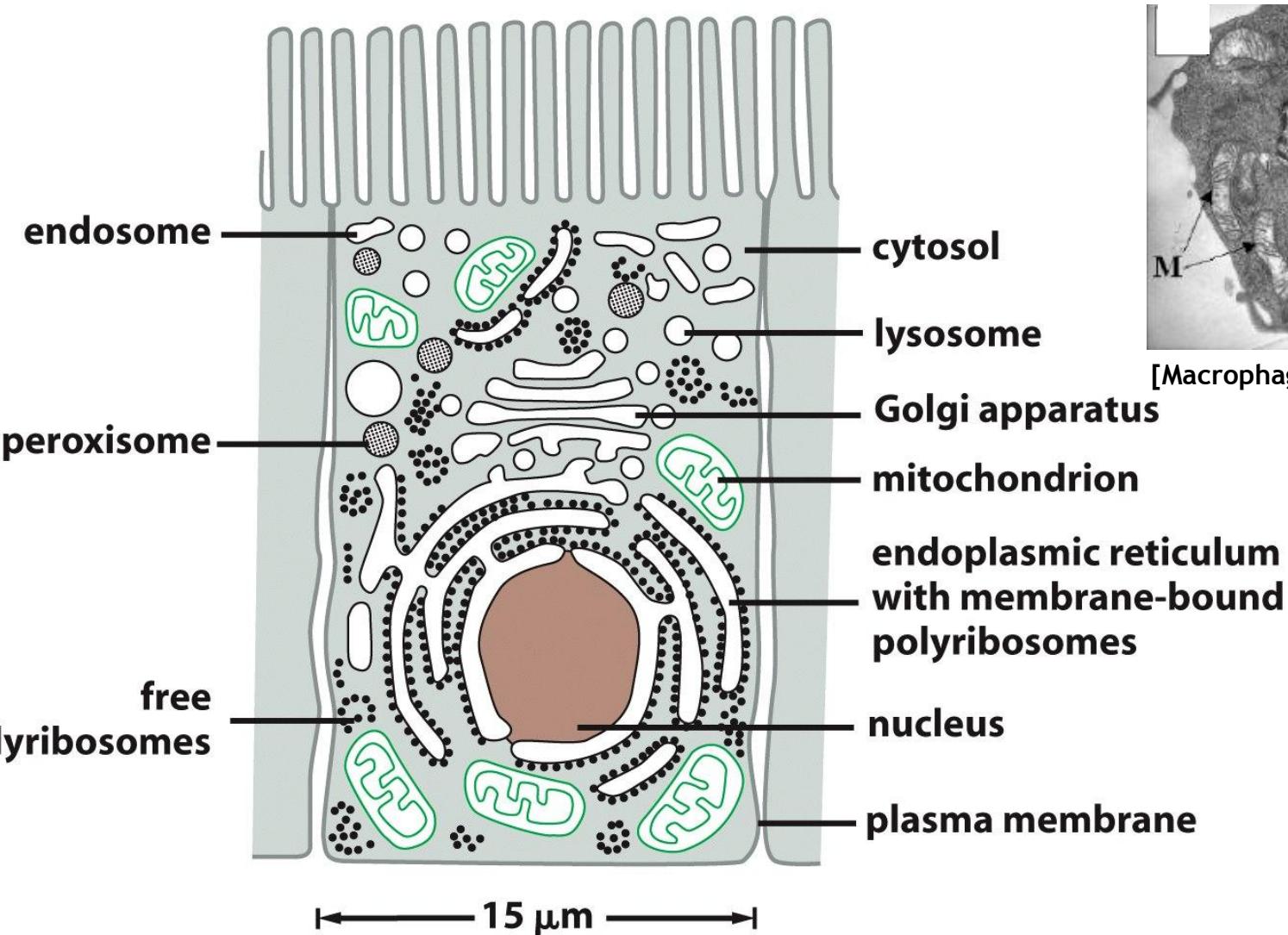


Prokaryotic Cells (Bacteria)



Eukaryotic Cells (Human, Animals)

!

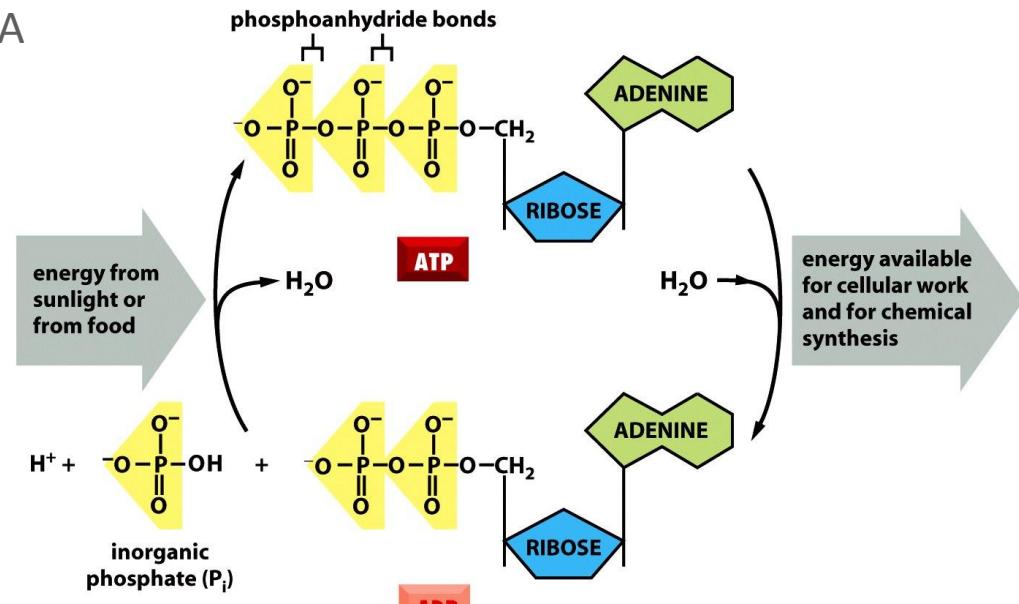


[Macrophage [Xia et al., 2006]

Living Systems Need a Constant Supply of Energy

Energy is used for

- mechanical work, e.g. muscle contraction or cellular movements
- active transport of molecules, e.g. across membranes
- synthesis of macromolecules, e.g. DNA



Energy can be provided by

- hydrolysis of energy rich bonds (ATP)
- electrochemical (proton or ion) gradients across a membrane

Energy can be generated by

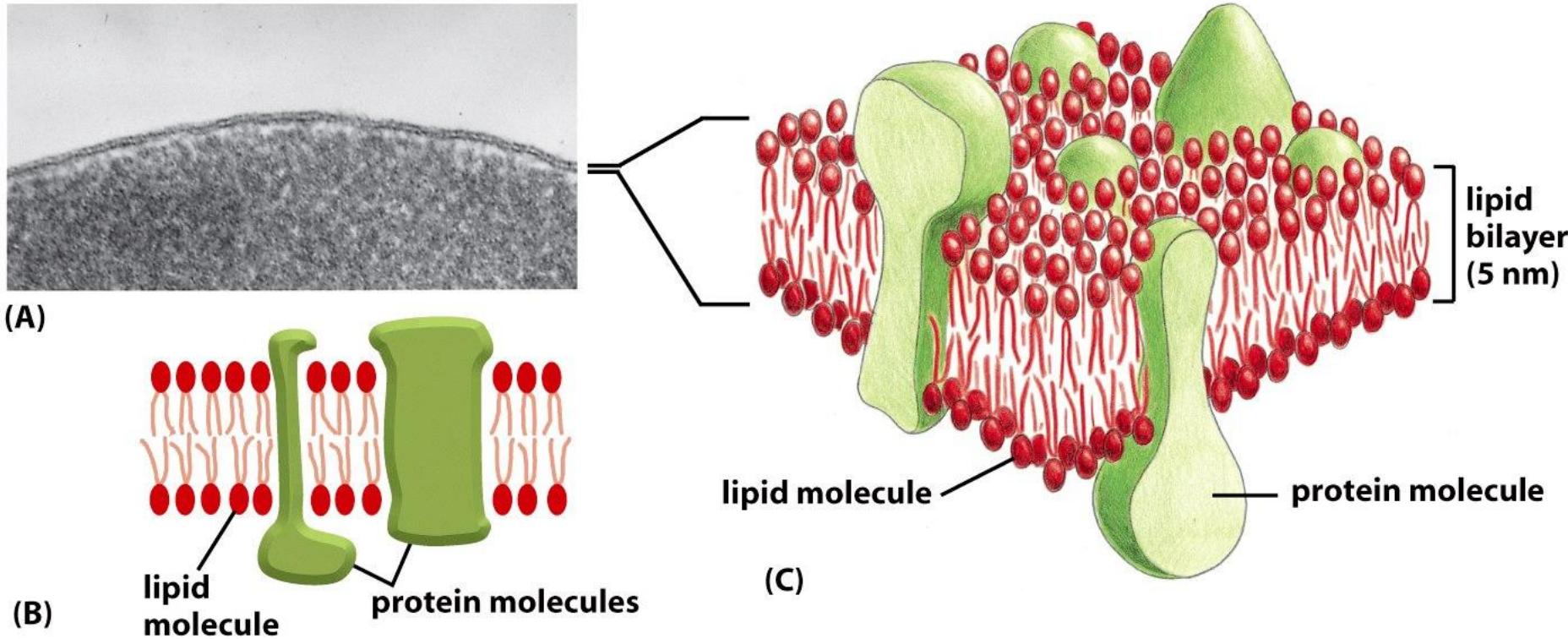
- controlled oxidation of (food) molecules through redox-reactions
- absorption of electromagnetic radiation (photosynthesis)

Cells are Surrounded by a Plasma Membrane

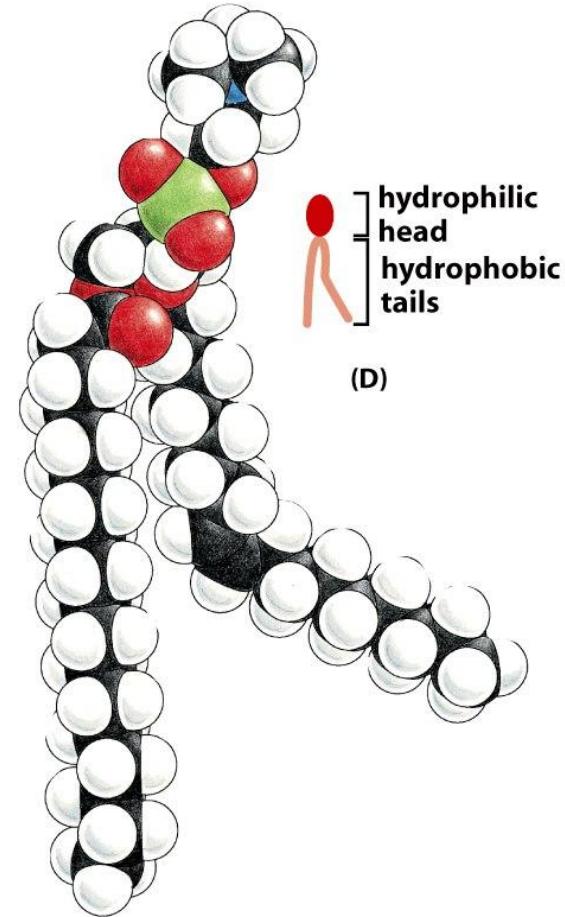
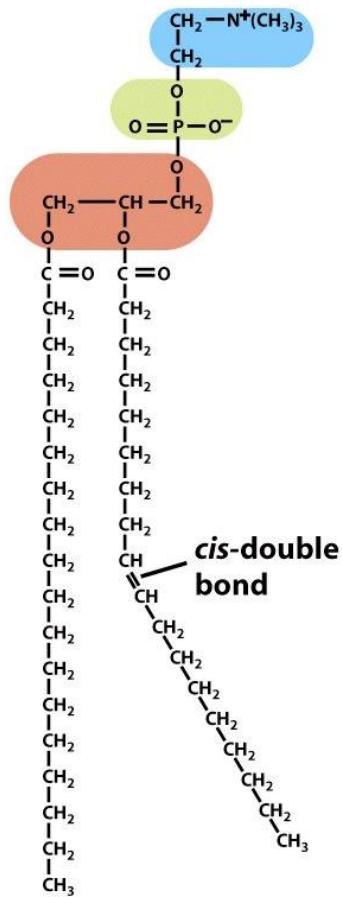
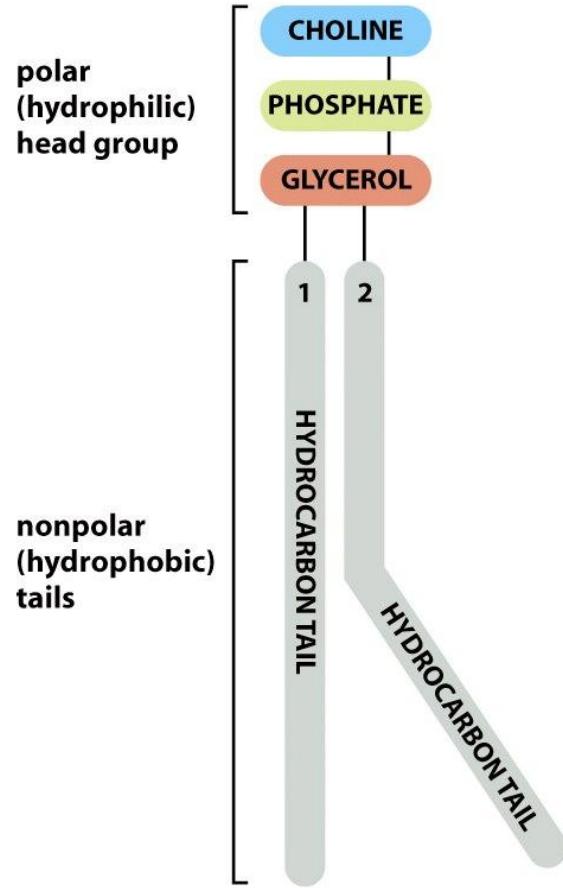
!

Cells are the basic units of all living organisms

„cellula“ (latin) „small chamber“



Phospholipids Are the Most Abundant Membrane Lipids

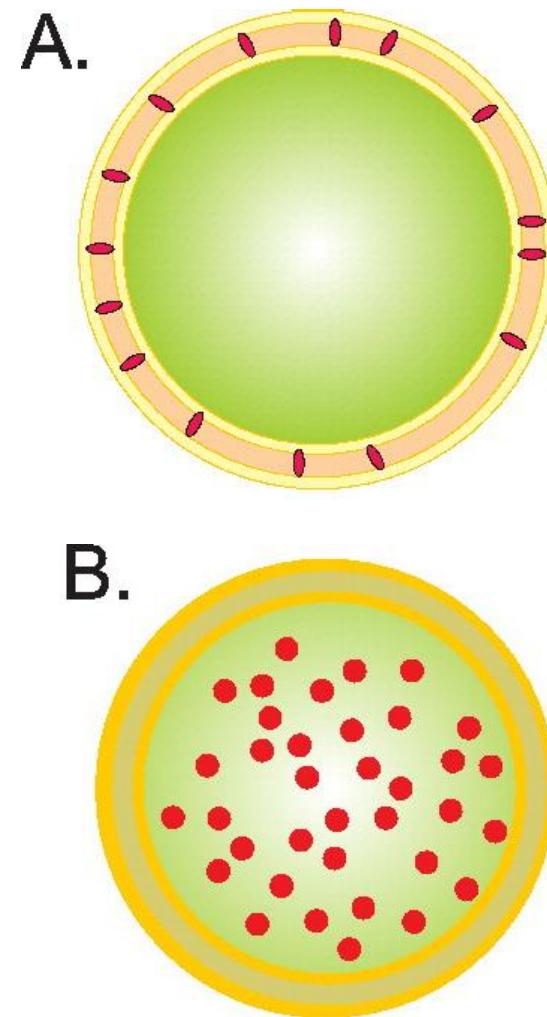
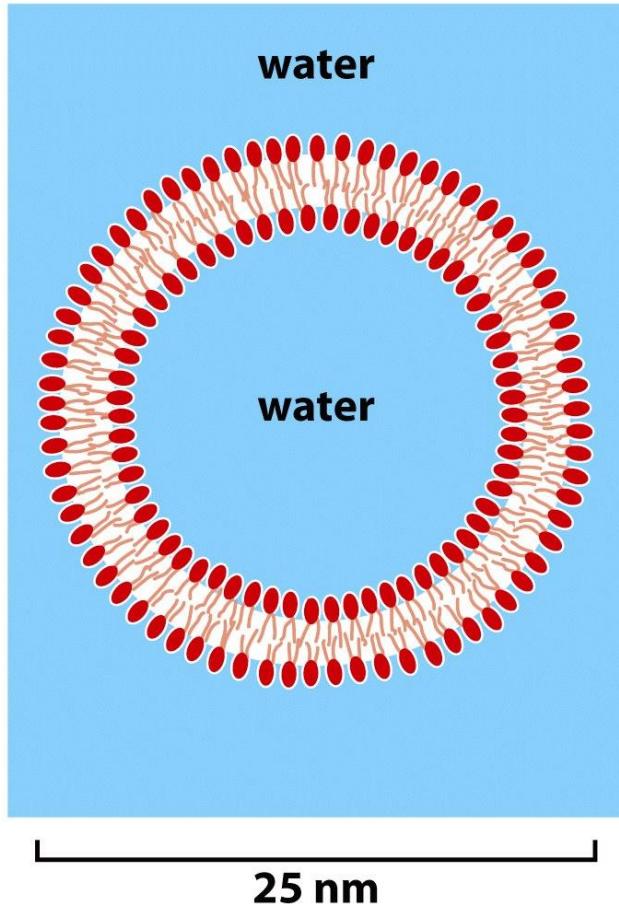


(A)

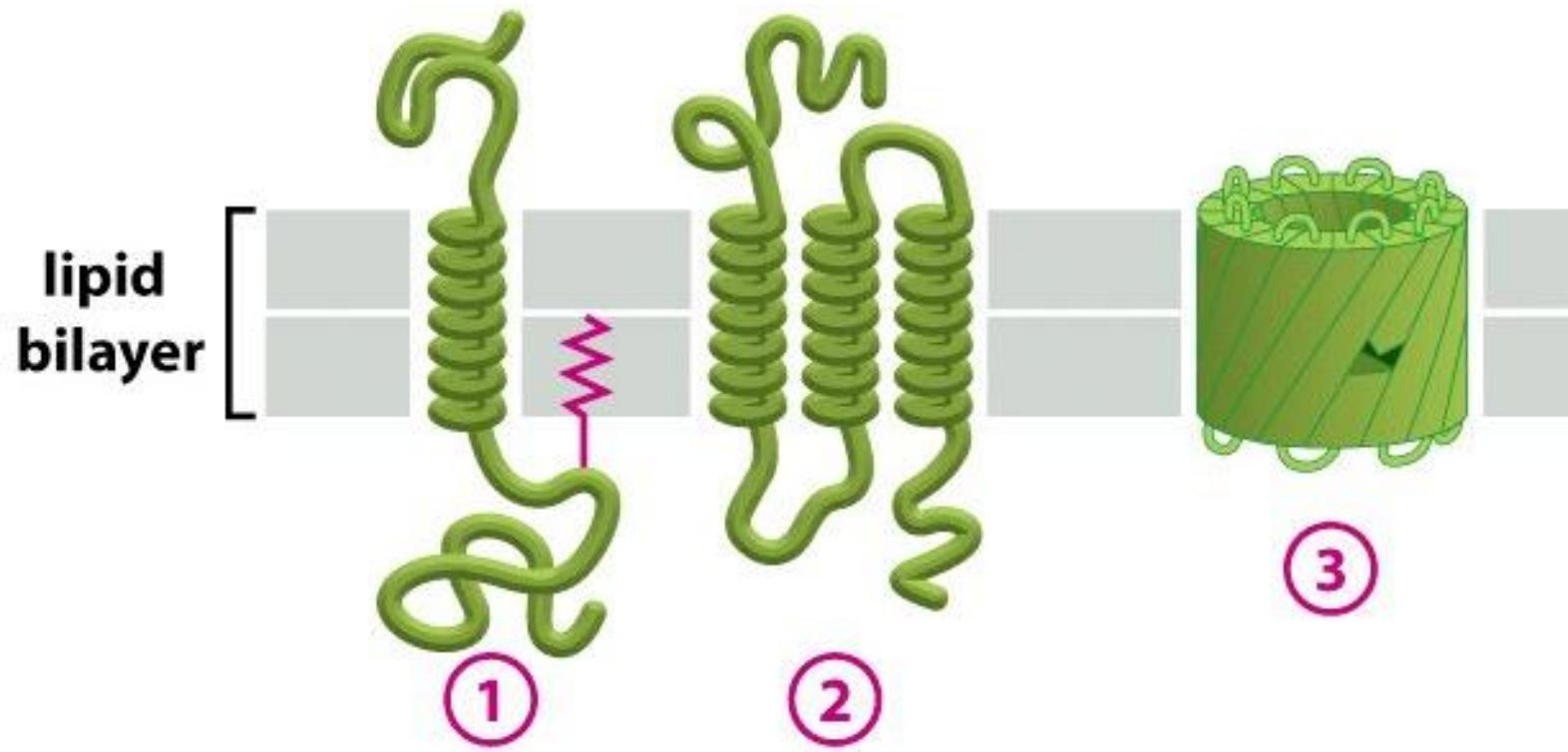
(B)

(C)

Liposomes



Membrane Proteins Mediate Many Membrane Functions



Transport Proteins Mediate Transfer of Solutes Across Membranes

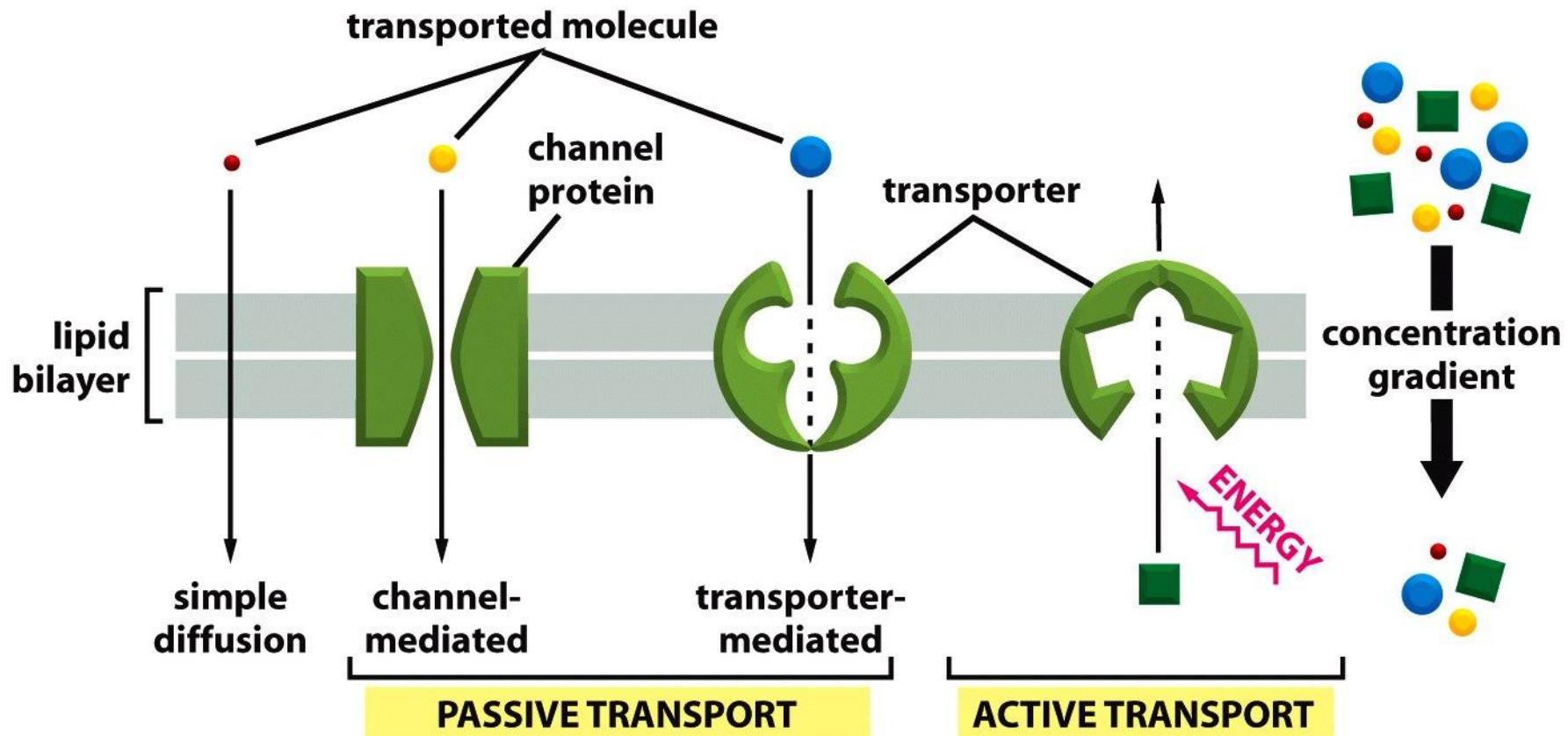
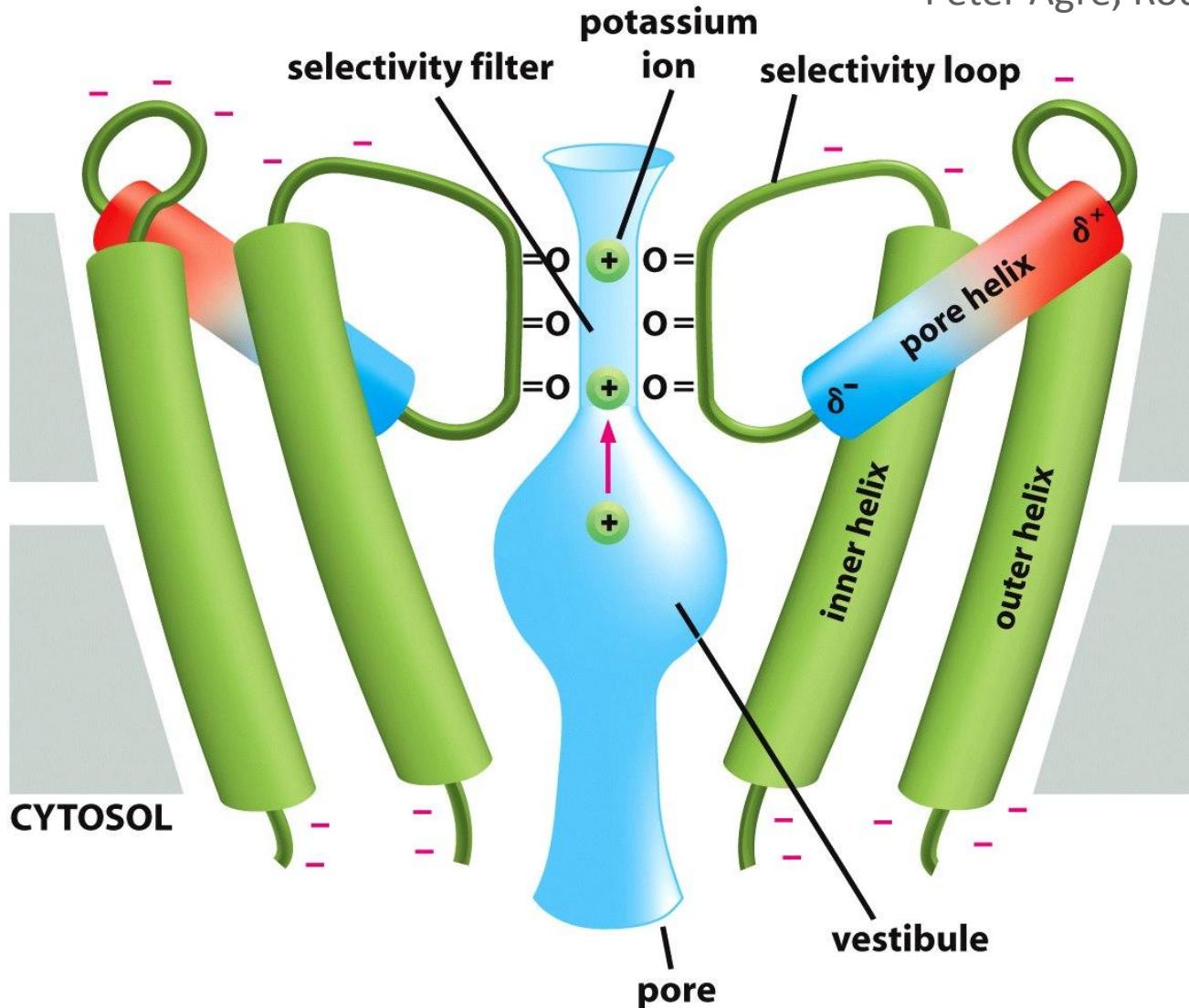


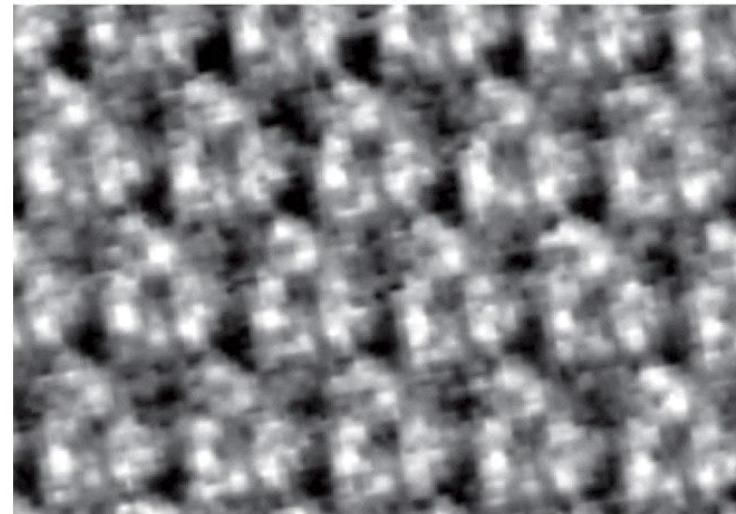
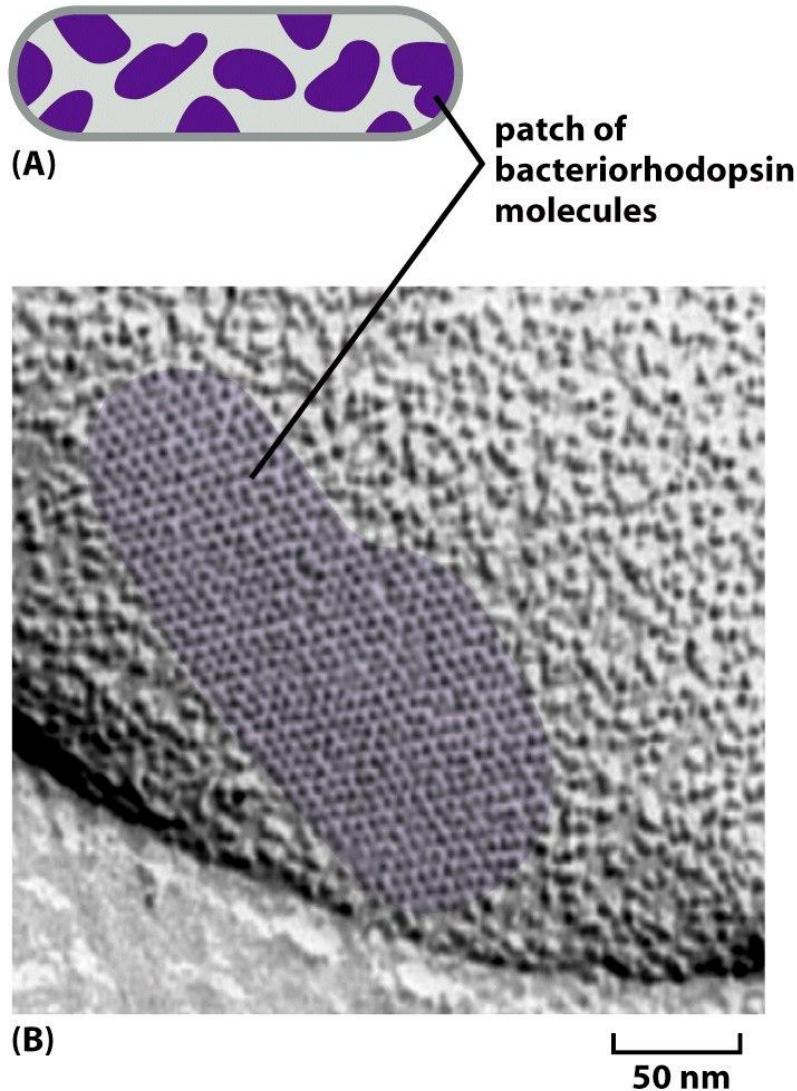
Figure 11-4a *Molecular Biology of the Cell* (© Garland Science 2008)

How K⁺ Channels Work

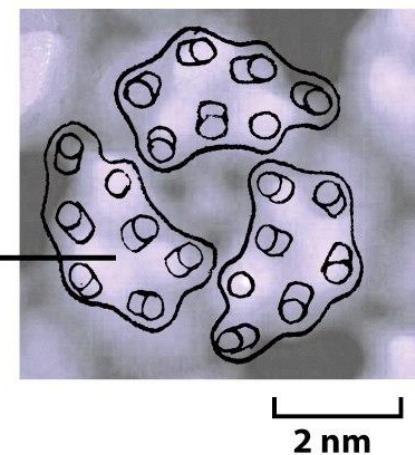
The Nobel Prize in Chemistry 2003
for „discoveries concerning
channels in cell membranes“
Peter Agre, Roderick MacKinnon



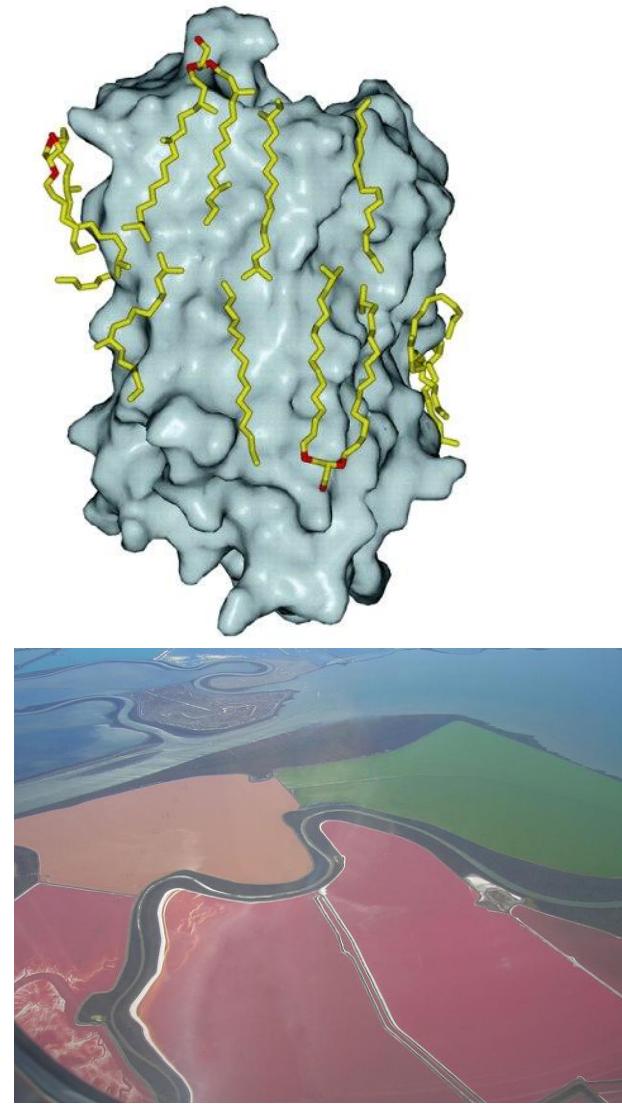
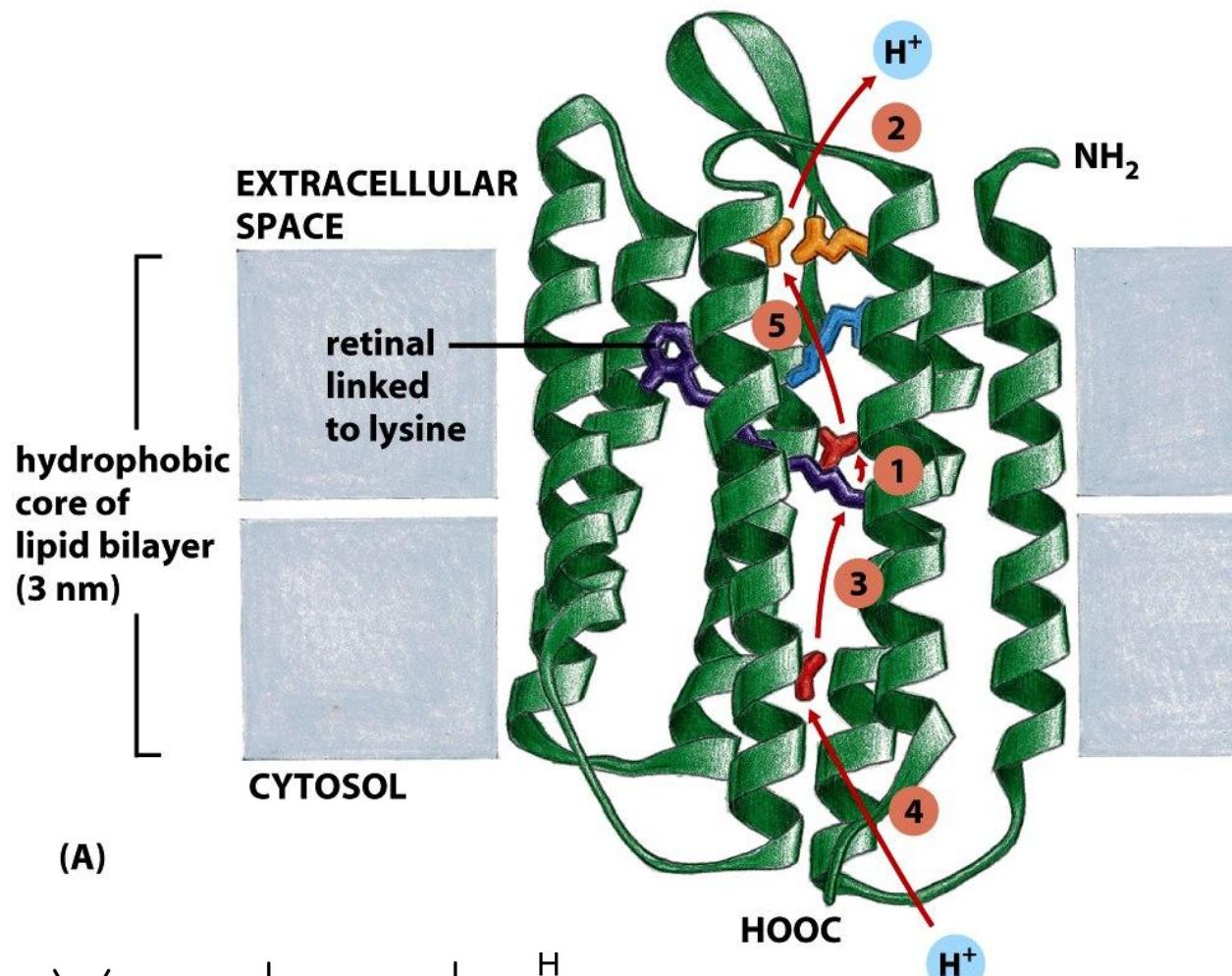
Bacteriorhodopsin a Light-Driven Proton Pump



(D)

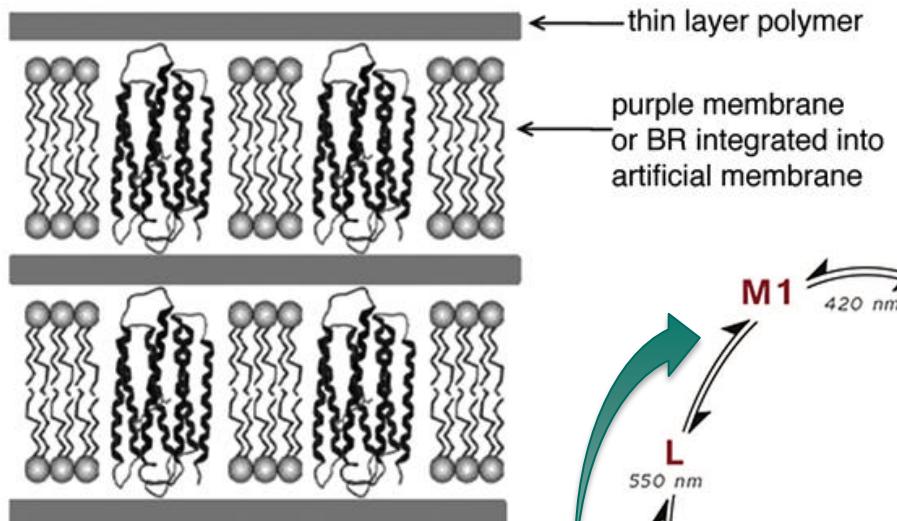


Structure of Bacteriorhodopsin

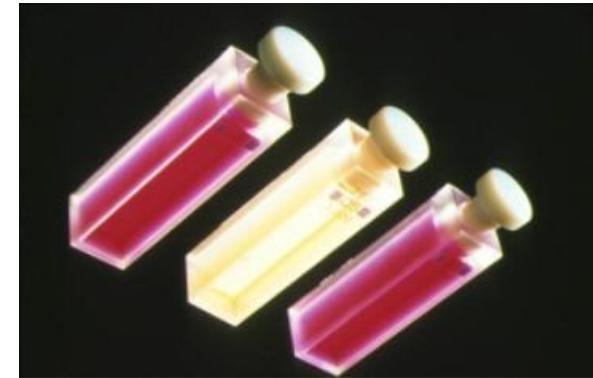
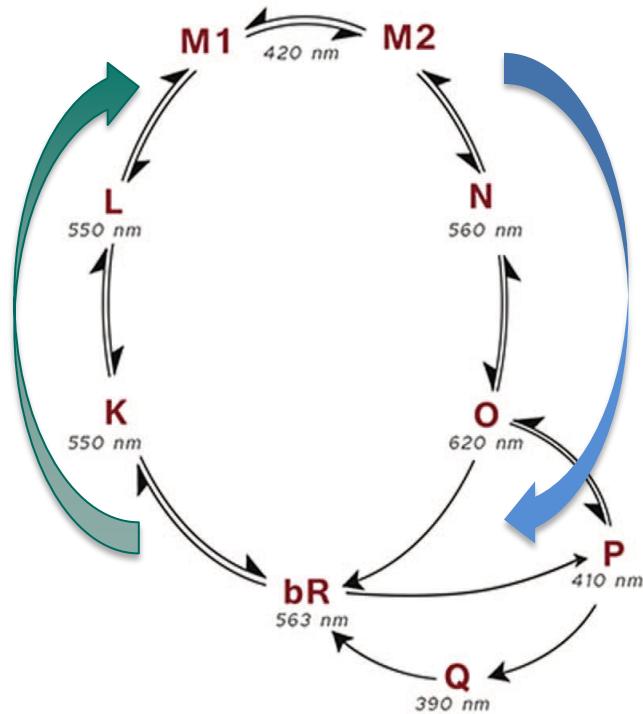


Applications of Bacteriorhodopsin

!



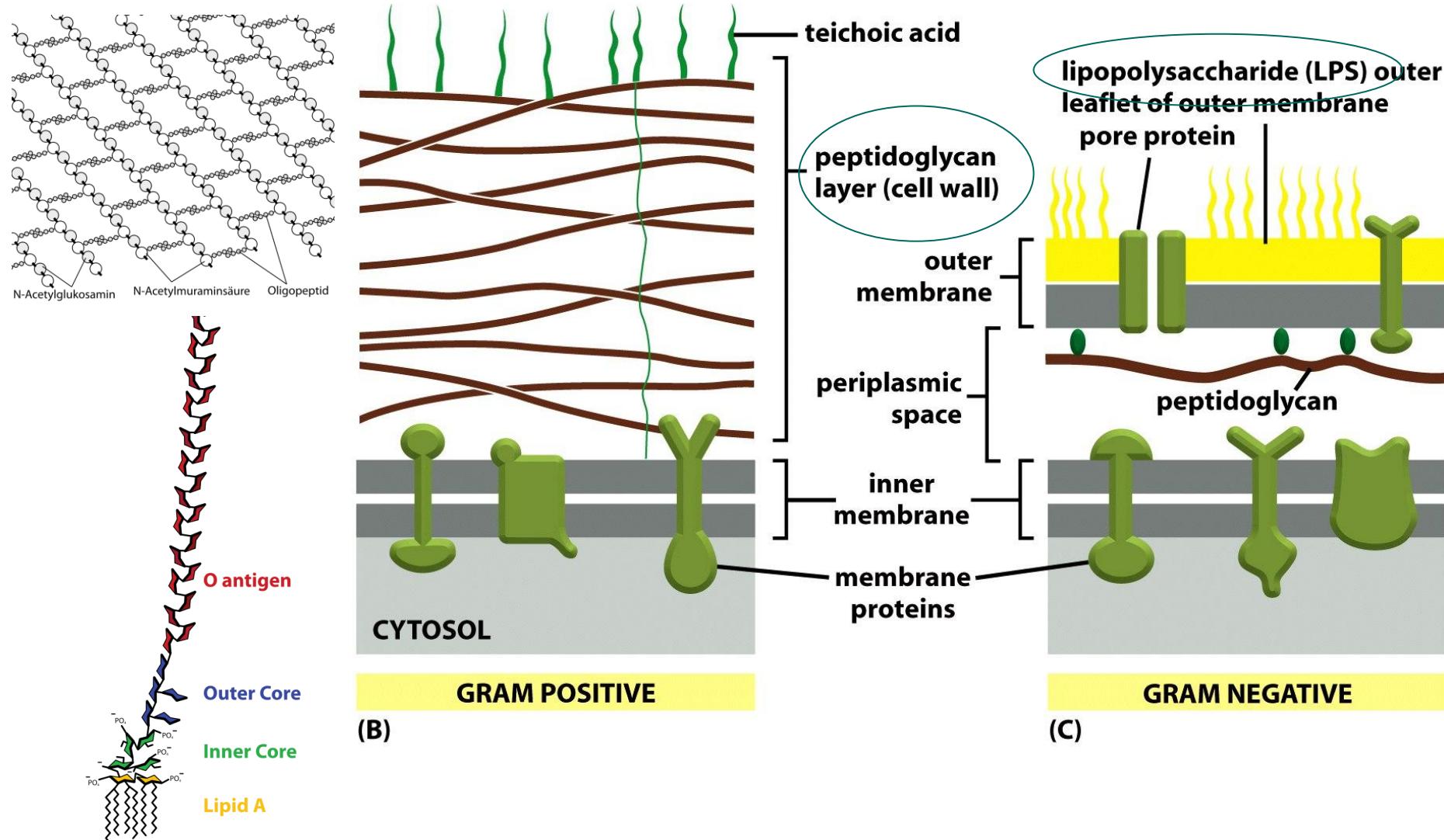
photocells for motion detection or artificial vision



molecular switches for anti-counterfeiting

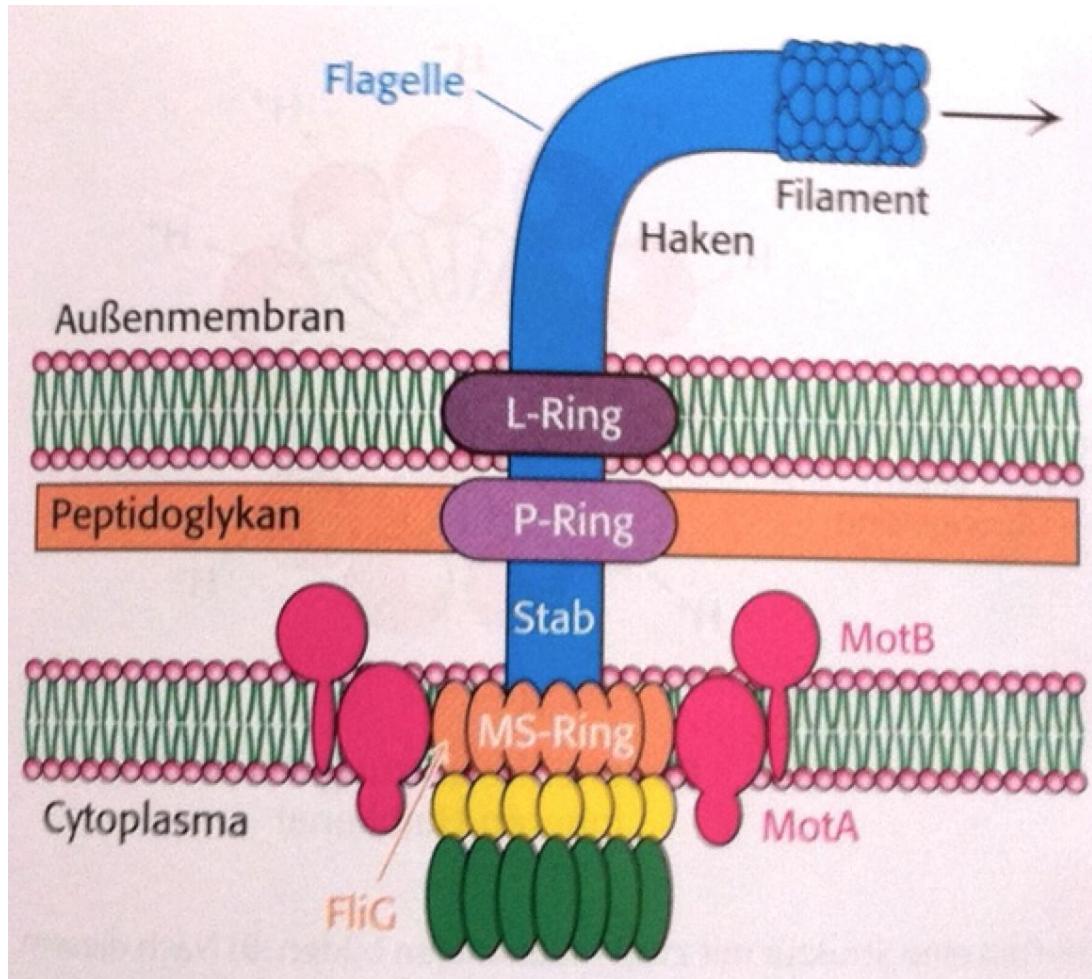


The Bacterial Cell Wall



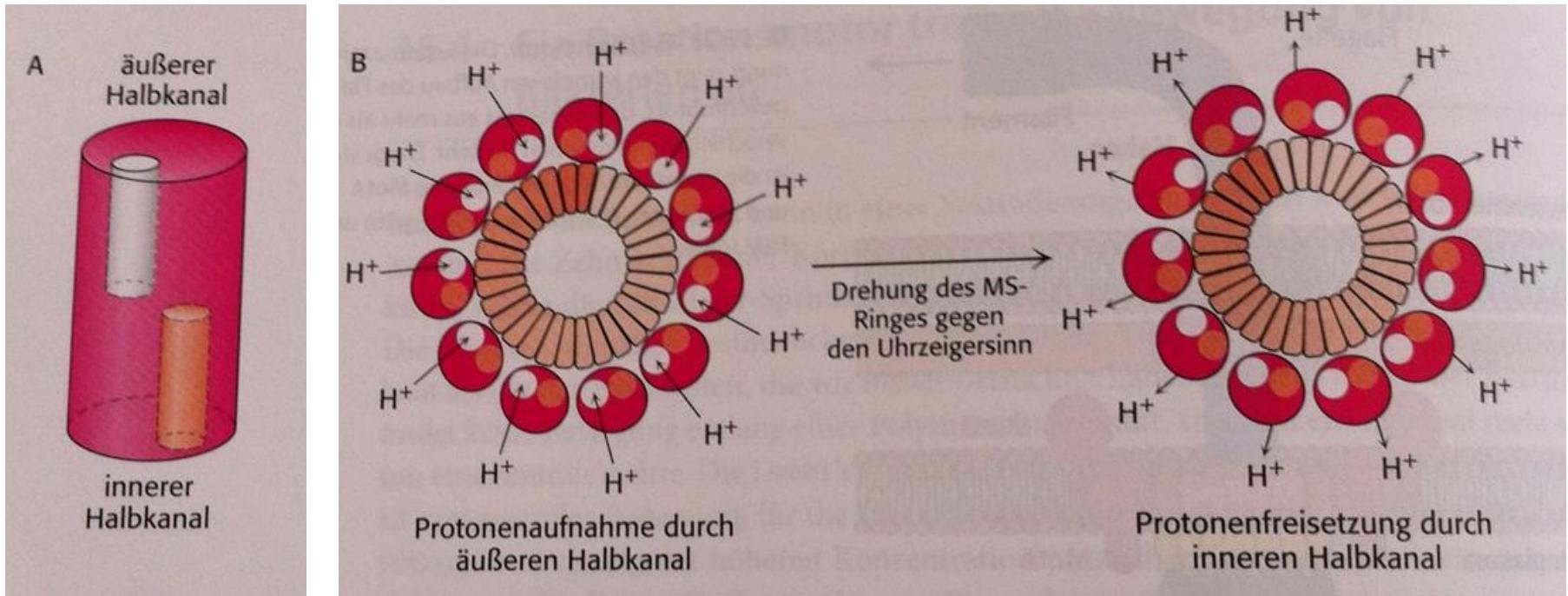
Flagella are Bacterial Molecular Motors

!



Flagellar Rotation is Driven by Proton Transport

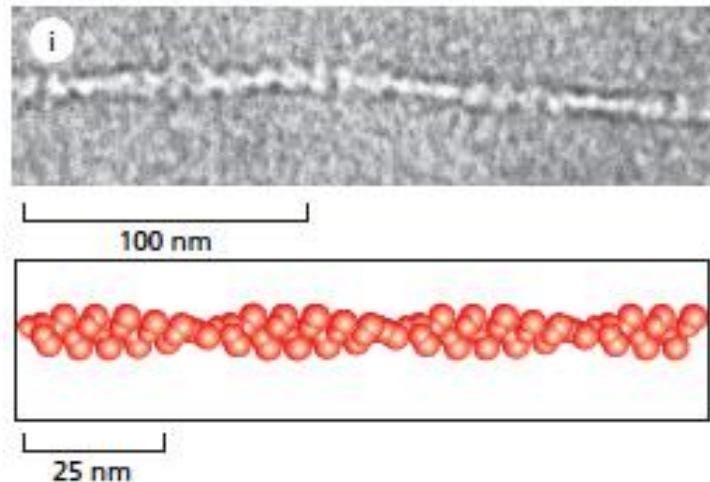
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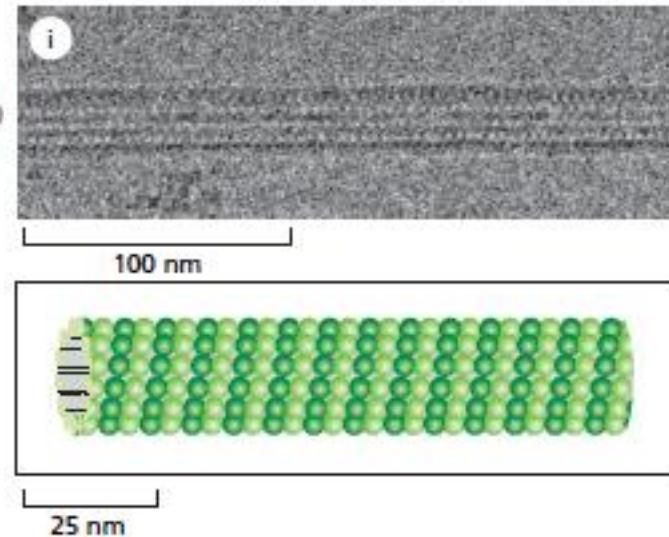
Flagella are Bacterial Molecular Motors



Cytoskeletal Filaments and Eukaryotic Motor Proteins



actin

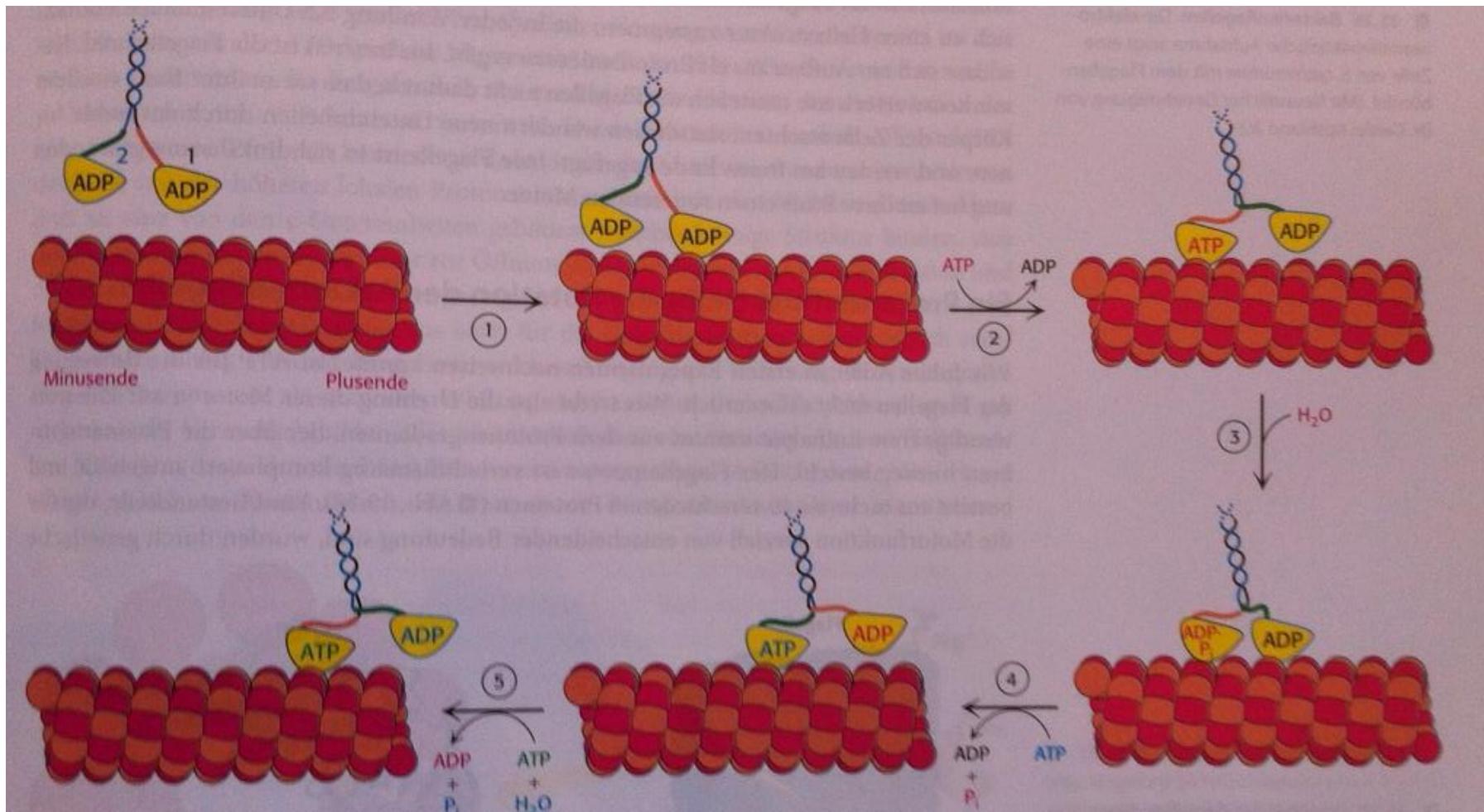


tubulin



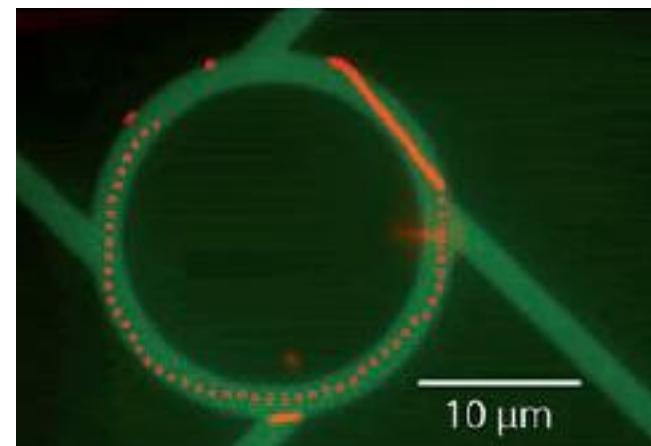
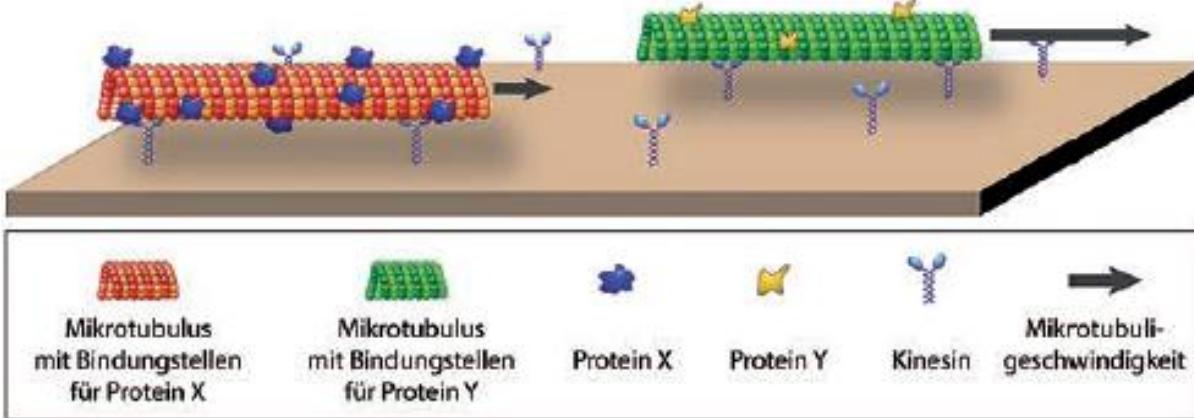
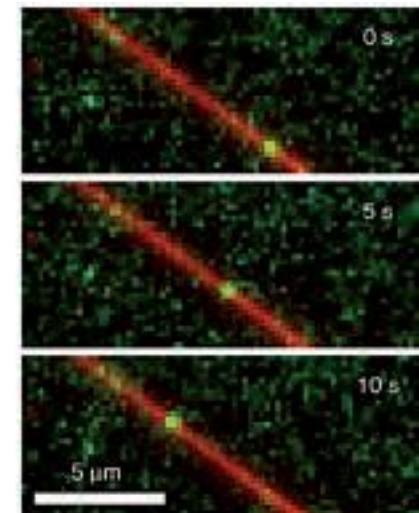
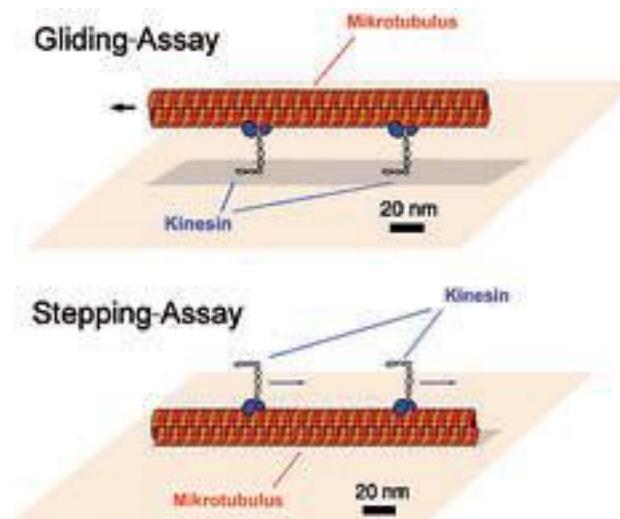
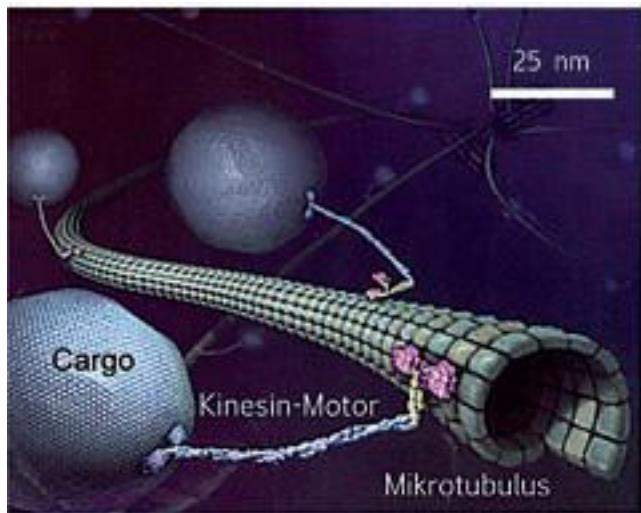
- Myosin
 - moves along actin filaments
 - muscle contraction
- Kinesin
 - moves along microtubules (towards the cell periphery)
 - transport of proteins, mRNA, and vesicles, separation of chromosomes during cell division
- Dynein
 - moves along microtubules (towards the centre of cells)
 - vesicle transport, movement of flagella

Kinesin Movement Along a Microtubule



Kinesin Microtubule Assays

!



Questions

- What is the biological function of DNA/RNA? What is this function based on? What are nucleotides and oligonucleotides? What is complementary base-pairing/hybridization? How can the melting point of DNA be determined? What is PCR? Explain its main principles.
- How can oligonucleotides be used for the assembly of nanoparticles? How can this be analyzed?
- What are DNA origami? Describe different approaches for their assembly? What are potential applications of DNA origami?
- What are eukaryotes and prokaryotes? What are the main differences between them?
- What are biological membranes? What is their composition? What are liposomes?
- How are molecules transported across biological membranes?
- What is bacteriorhodopsin? What are potential applications based on bacteriorhodopsin?
- Give examples of motor proteins and their biological function. What is the kinesin microtubule assay?

Literature

Books:

- Molecular Biology of the Cell, ed. Alberts et al. (2008), Garland Science
- Biochemie, Stryer, (2012) Springer

Articles:

- Mirkin et al., 1996, Nature 382: 607 A DNA based method for rationally assembling nanoparticles into macroscopic materials
- Saccà and Niemeyer, 2012, DNA Origami: the art of folding DNA
- Schreiber et al., 2014, Hierarchical assembly of metal nanoparticles, quantum dots and dyes using DNA origami scaffold
- Douglas et al., 2012, A logic-Gated Nanorobot for targeted transport of molecular payloads
- Saeedi et al., 2012, Potential applications of bacteriorhodopsin mutants. Bioengineered 3: 326
- Allen and Cullis, 2013, Liposomal Drug Delivery Systems, Advanced Drug Delivery Reviews 65: 36
- Diez, 2009, Biomolekulare Motoren als Nanoroboter, Biospektrum 5: 522

Next Lecture: May 3, 2019

Cell and Tissue Functions