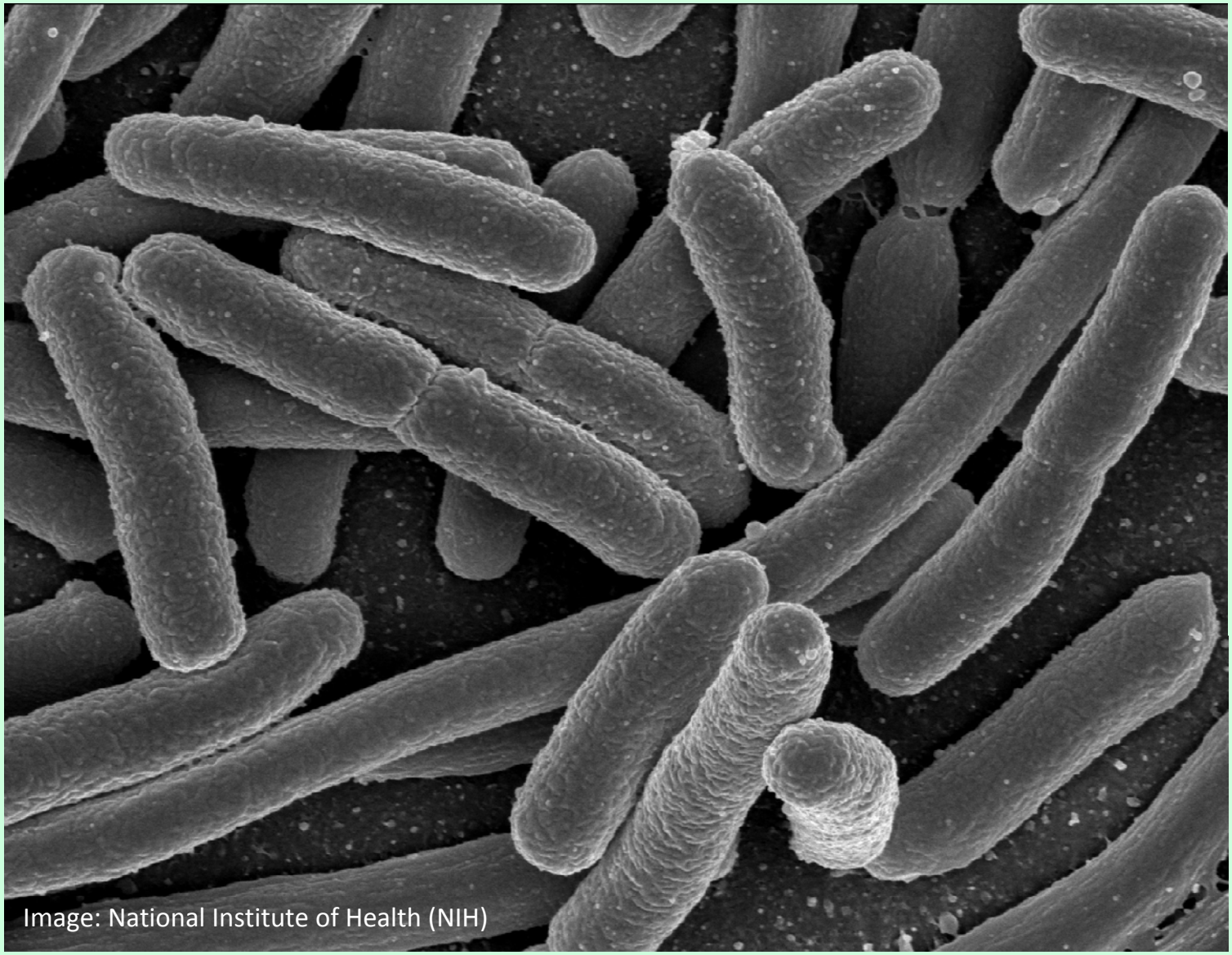

Image: National Institute of Health (NIH)

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Overview

Single-Celled Organism	Locomotion Method	Resulting Technology
Bacteria	Swimming	?
	Sliding	
Protista	Swimming	
	Shape Change	

Living at very low Reynold numbers

$$\text{Reynold Number} = \frac{\text{speed x width obstacle x density fluid}}{\text{viscosity fluid}}$$

$$R = \frac{\text{inertia forces}}{\text{viscous forces}}$$

Living at very low Reynold numbers

$$R = \frac{\text{inertia forces}}{\text{viscous forces}}$$

Single-celled organisms: R very low, around 10^{-4}

Scaling down: Volume^3, Surface^2

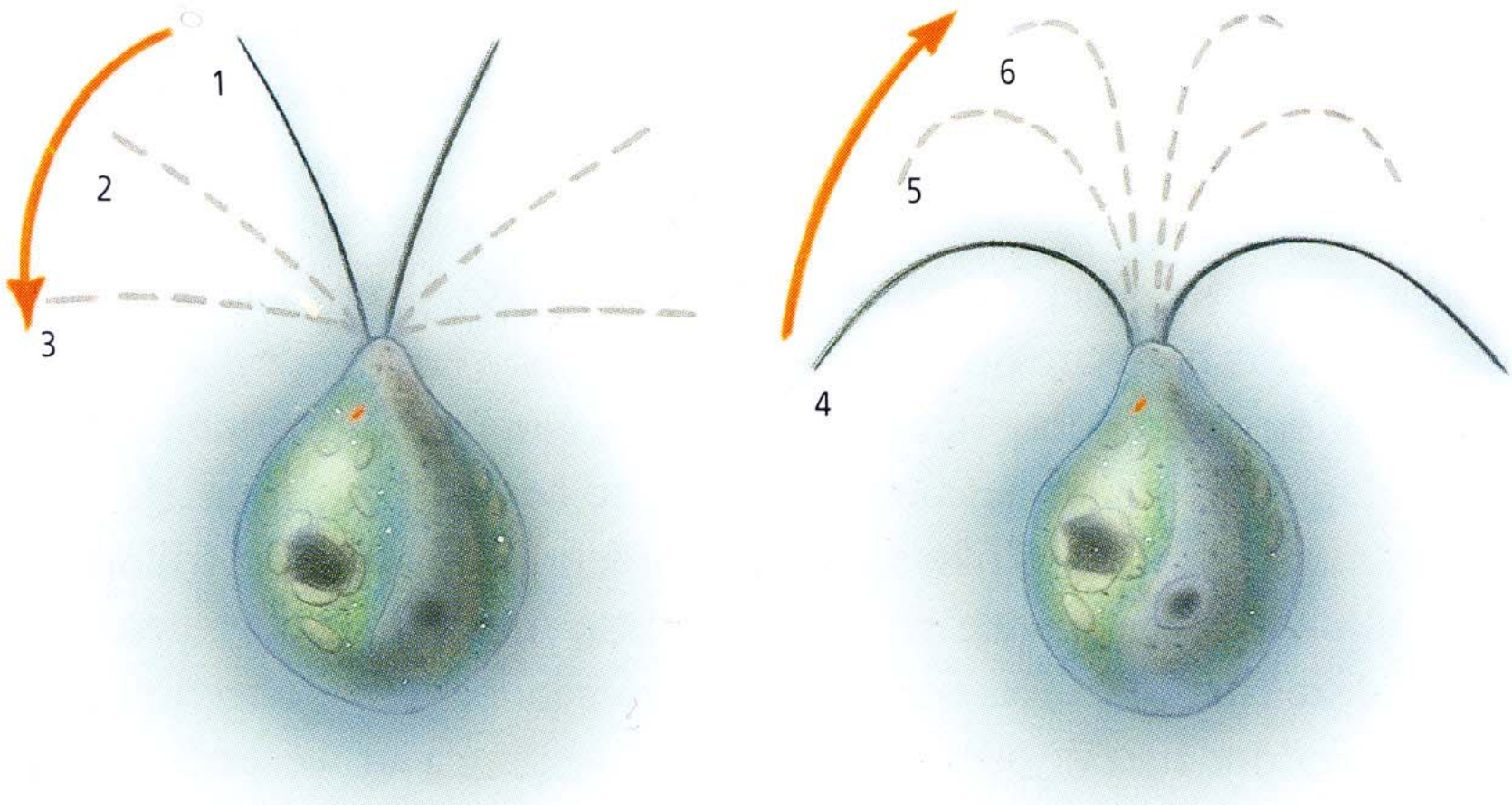
→ Inertia plays no role

→ Viscosity completely dominant

Swimming through very thick sirop

Movements must be irreversible!

Bac-Swim	Bac-Slide	Prot-Swim	Prot-Shape



Movements must be irreversible!

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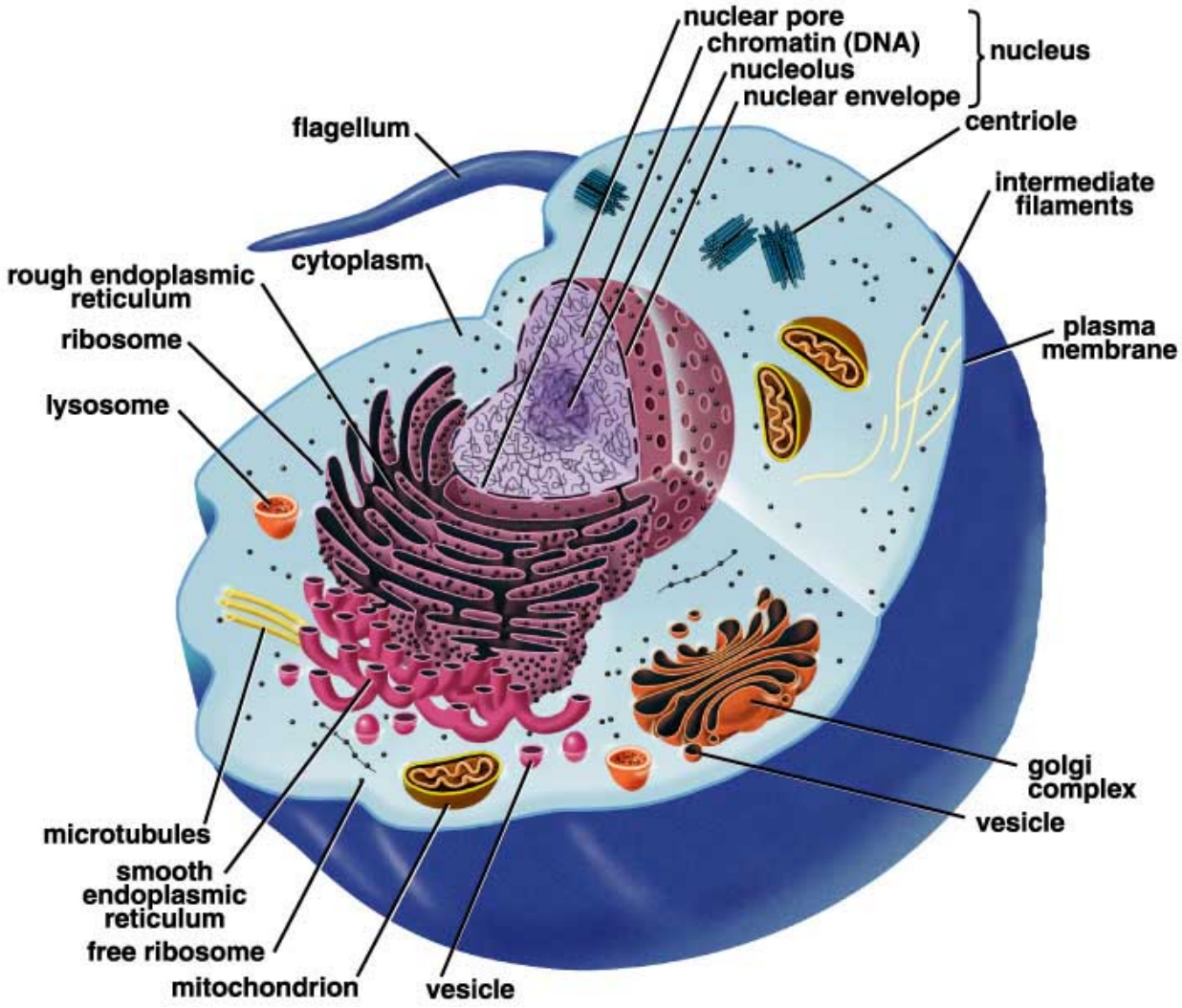
nuclear pore
chromatin (DNA)
nucleolus
nuclear envelope
nucleus
flagellum
centriole
intermediate filaments
cytoplasm
rough endoplasmic reticulum
ribosome
plasma membrane
lysosome
golgi complex
vesicle
microtubules
smooth endoplasmic reticulum
free ribosome
mitochondrion
vesicle

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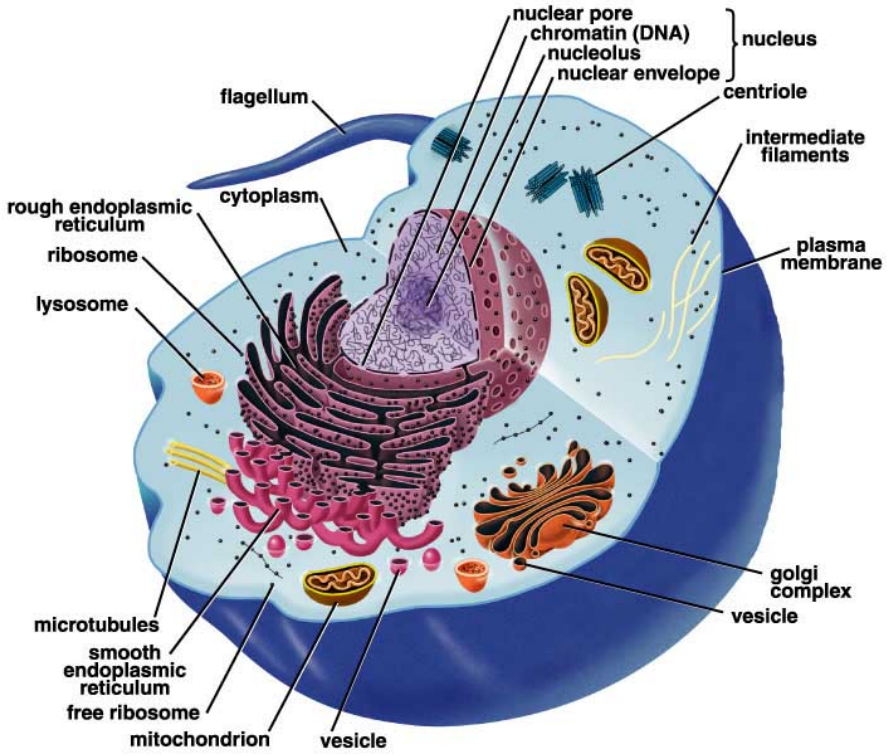
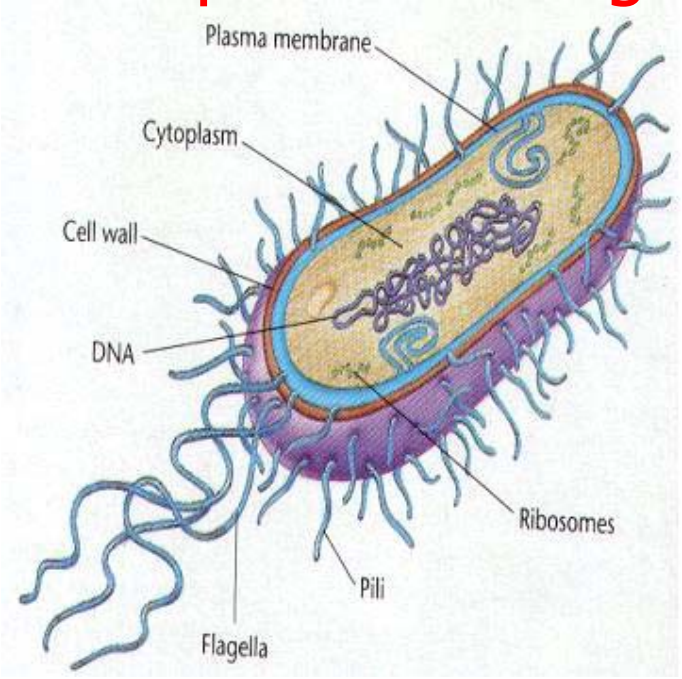


Bacteria:

- Very small (0.1–40µm)
- No specialized organs



Protista:

- Quite large (max 2mm)
- Specialized organs (nucleus, organellas)

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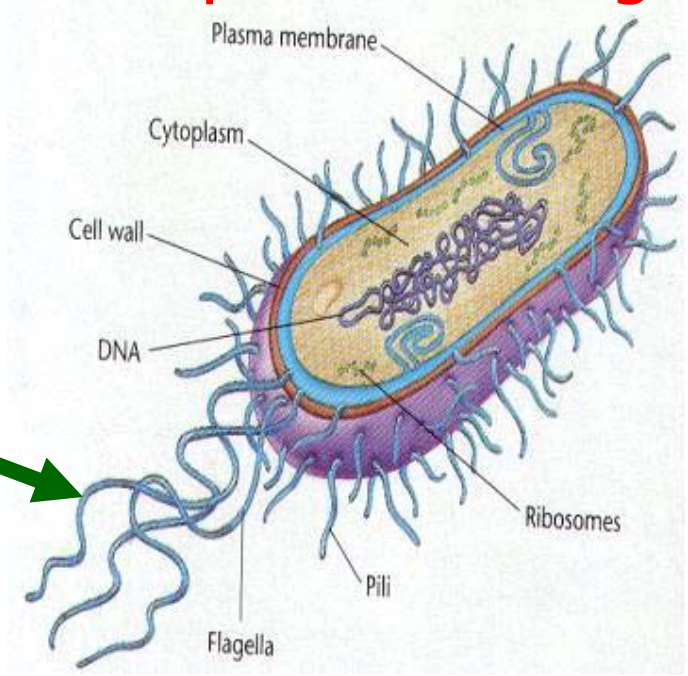
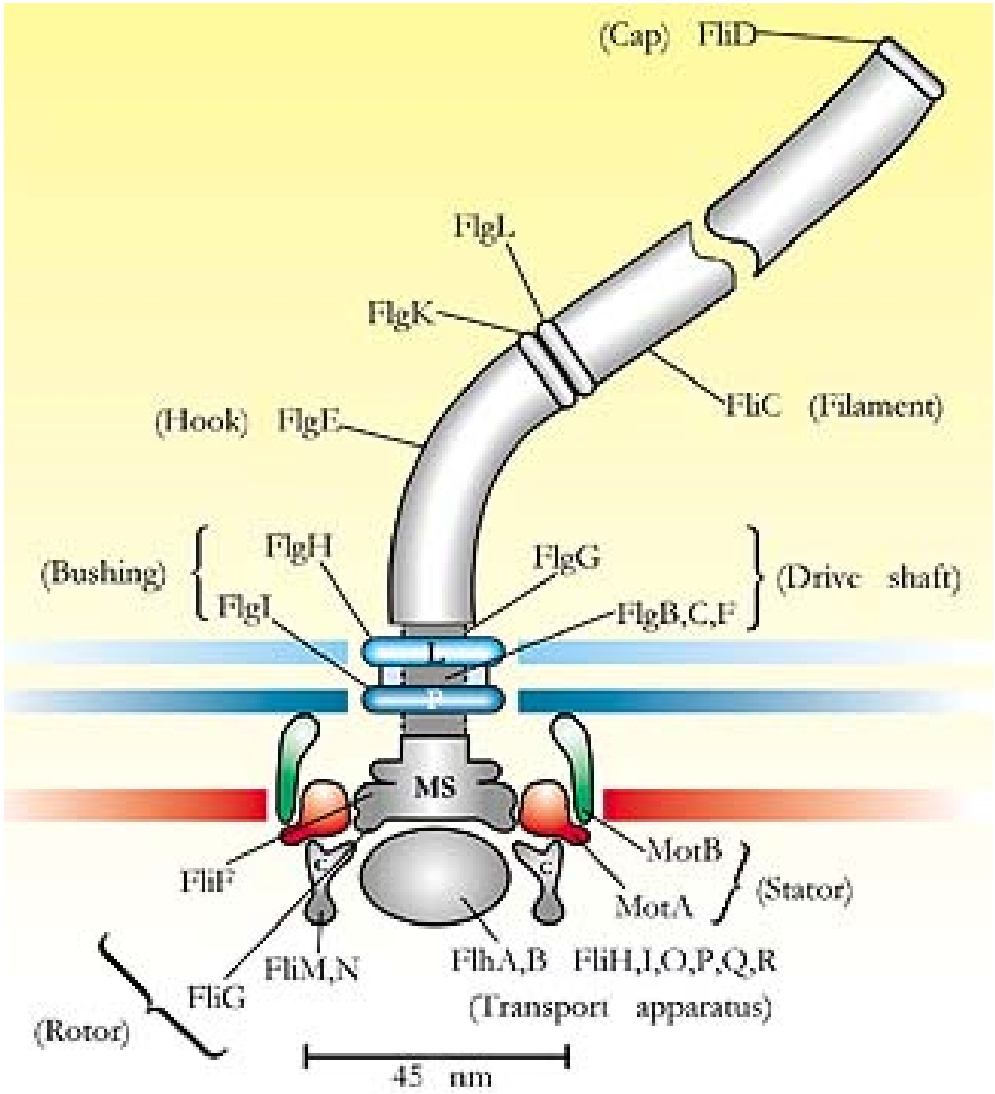
Flagellum:

- Hollow fibre, 20nm thick
- Performs *rotating* motion
- Sharp bend near cell membrane

Bacteria:

- Very small (0.1–40µm)
- No specialized organs





"Hook"

Double Bearing

Rotary Engine

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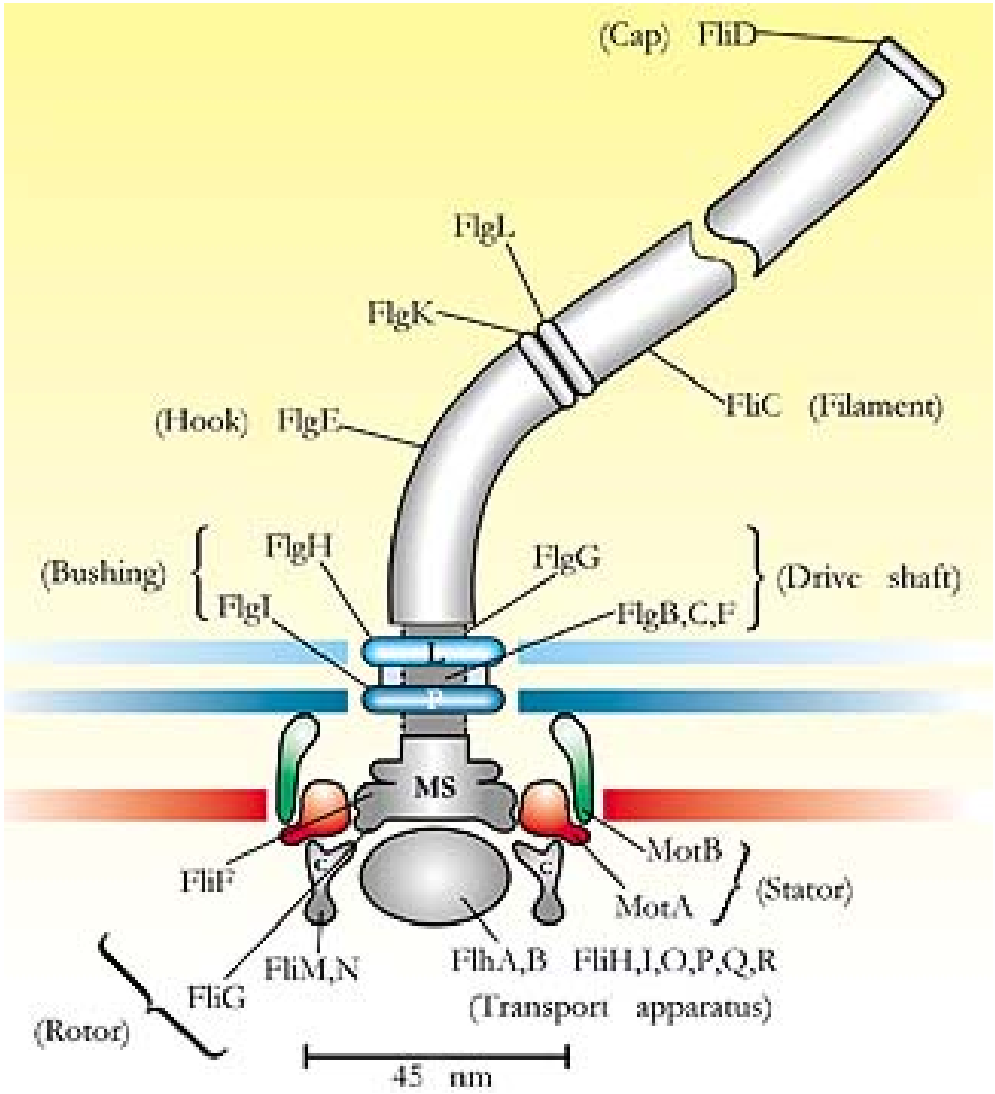
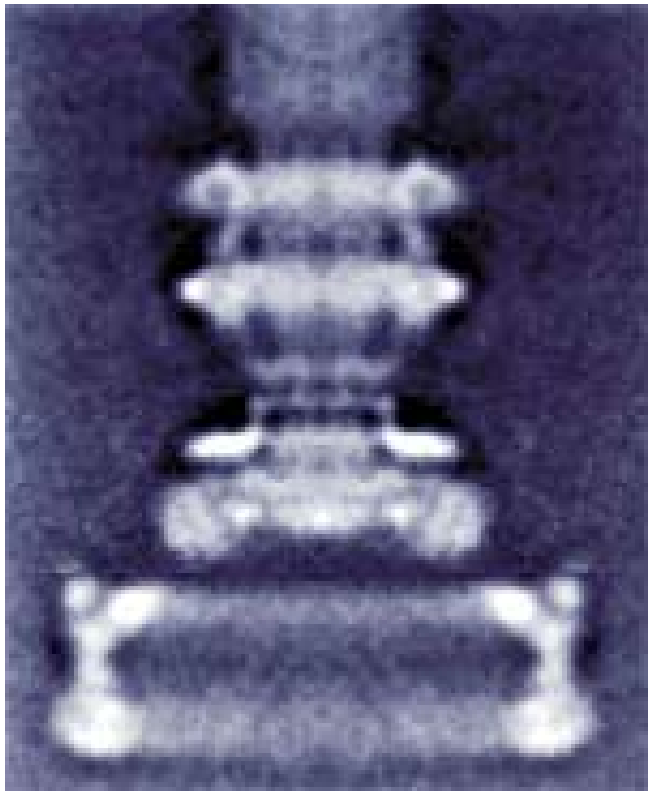

(Cap) FliD
FlgL
FlgK
FliC (Filament)
(Hook) FlgE
(Bushing)
FlgH
FlgI
FlgG
FlgB,C,F
(Drive shaft)
MS
MotB
MotA
(Stator)
FliF
FliM,N
FliG
(Rotor)
FlhA,B FliH,I,O,P,Q,R
(Transport apparatus)
45 nm



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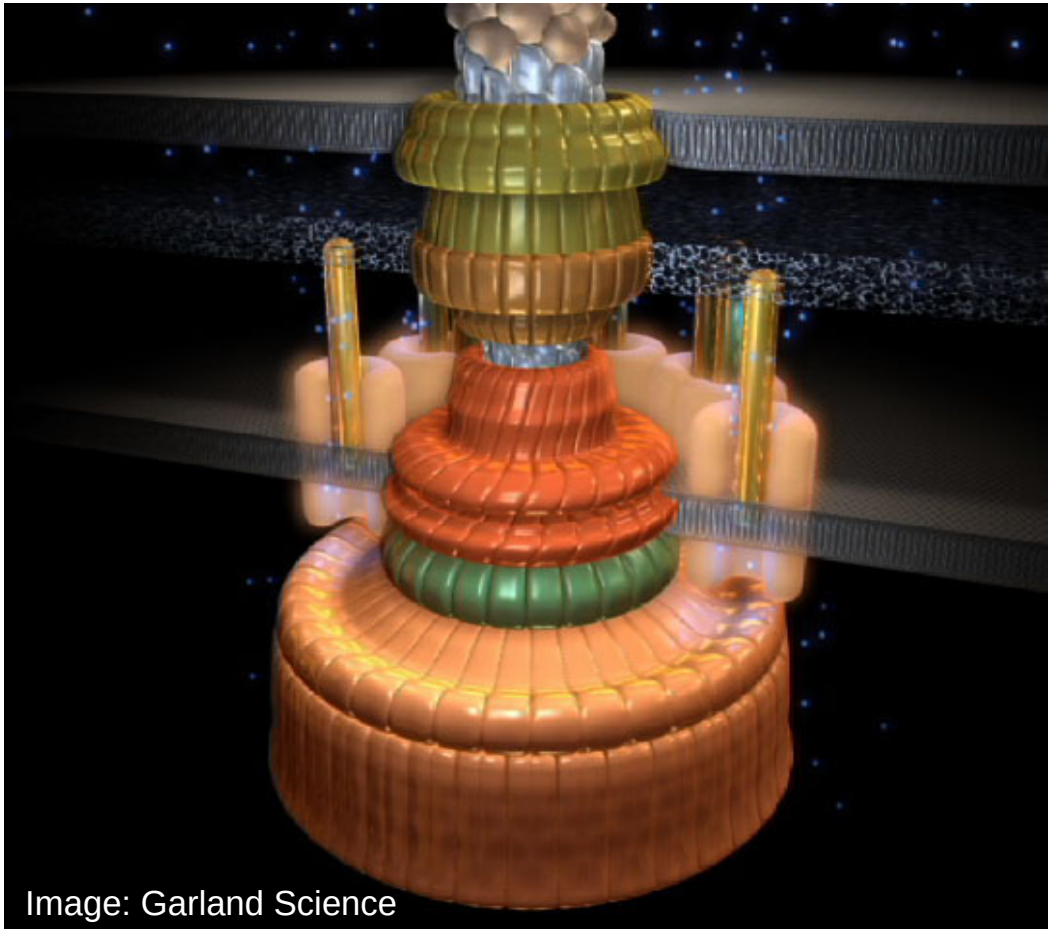


Image: Garland Science

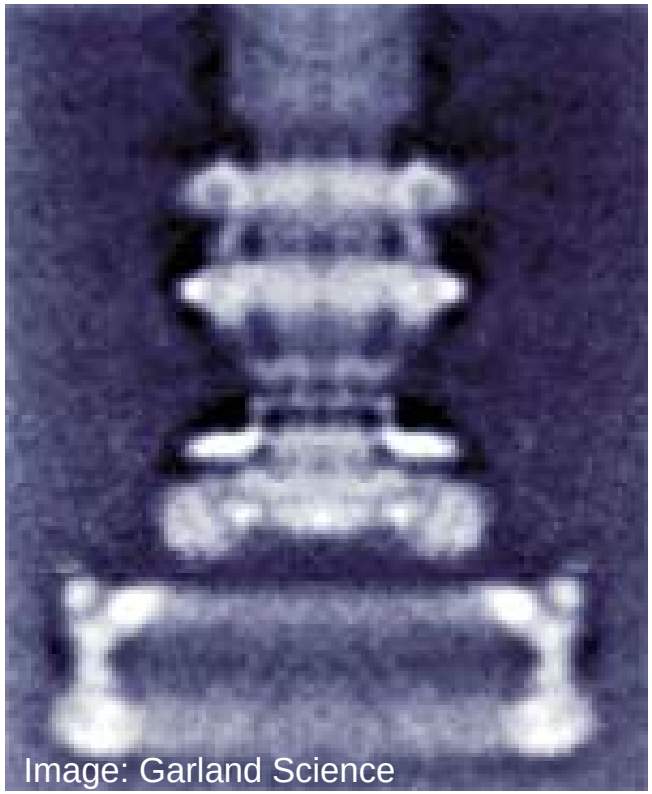


Image: Garland Science

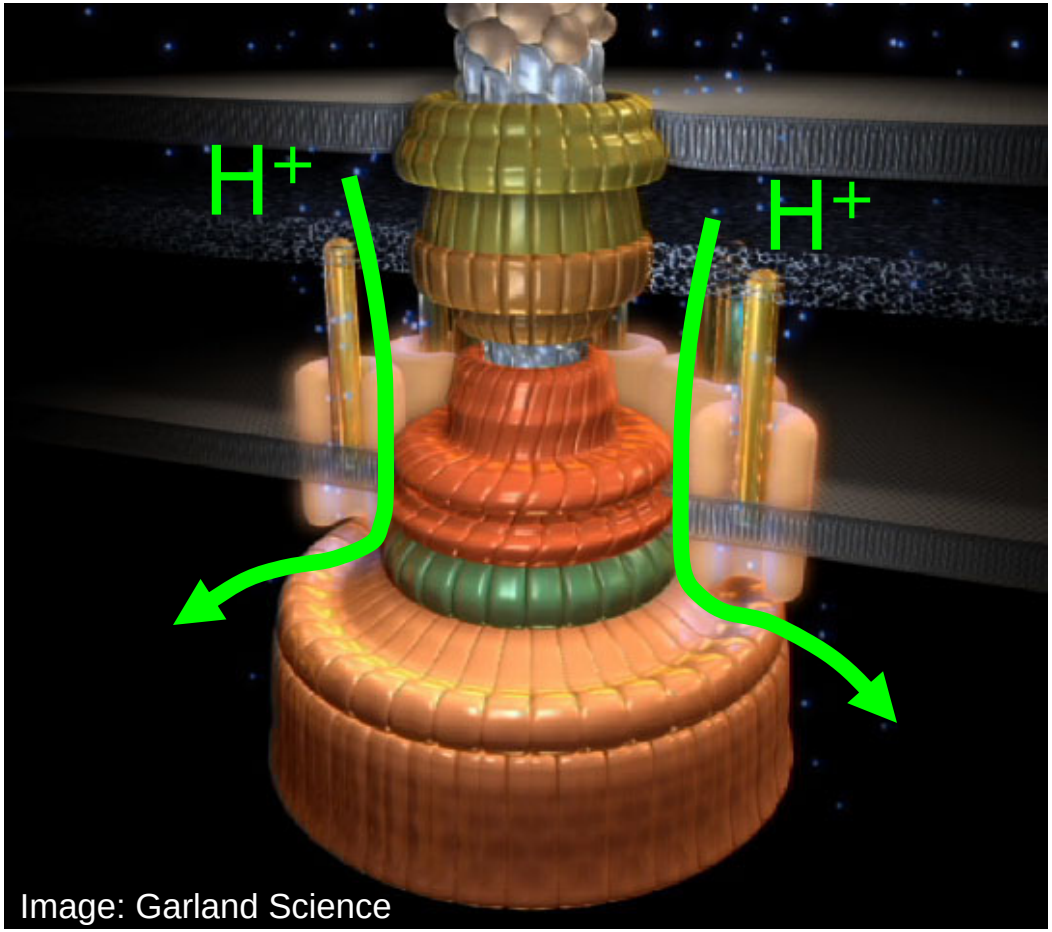


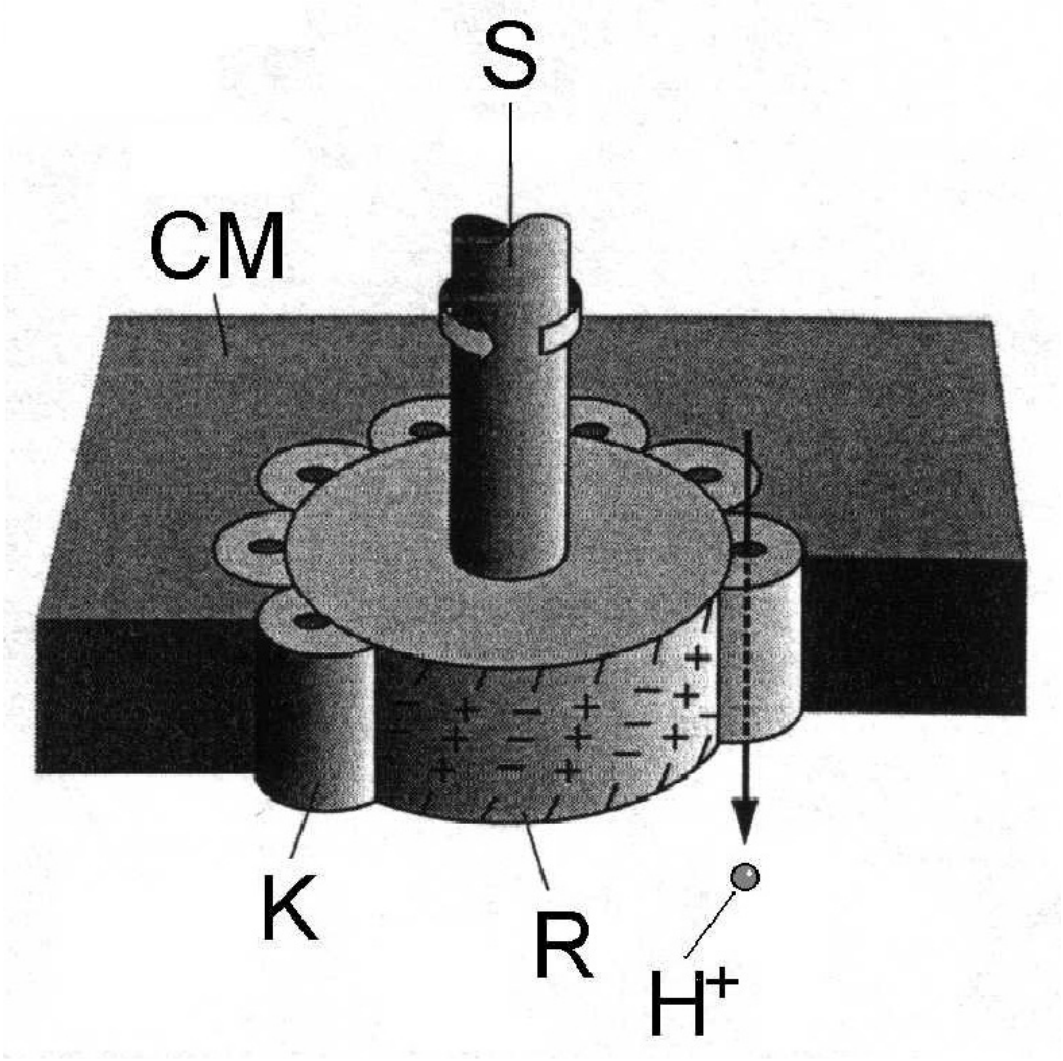
Image: Garland Science

H+ concentration outside cell always larger

H+ ions move along rotor

Rotor is charged along slanting lines

Angle slope defines speed (200-1000rpm)



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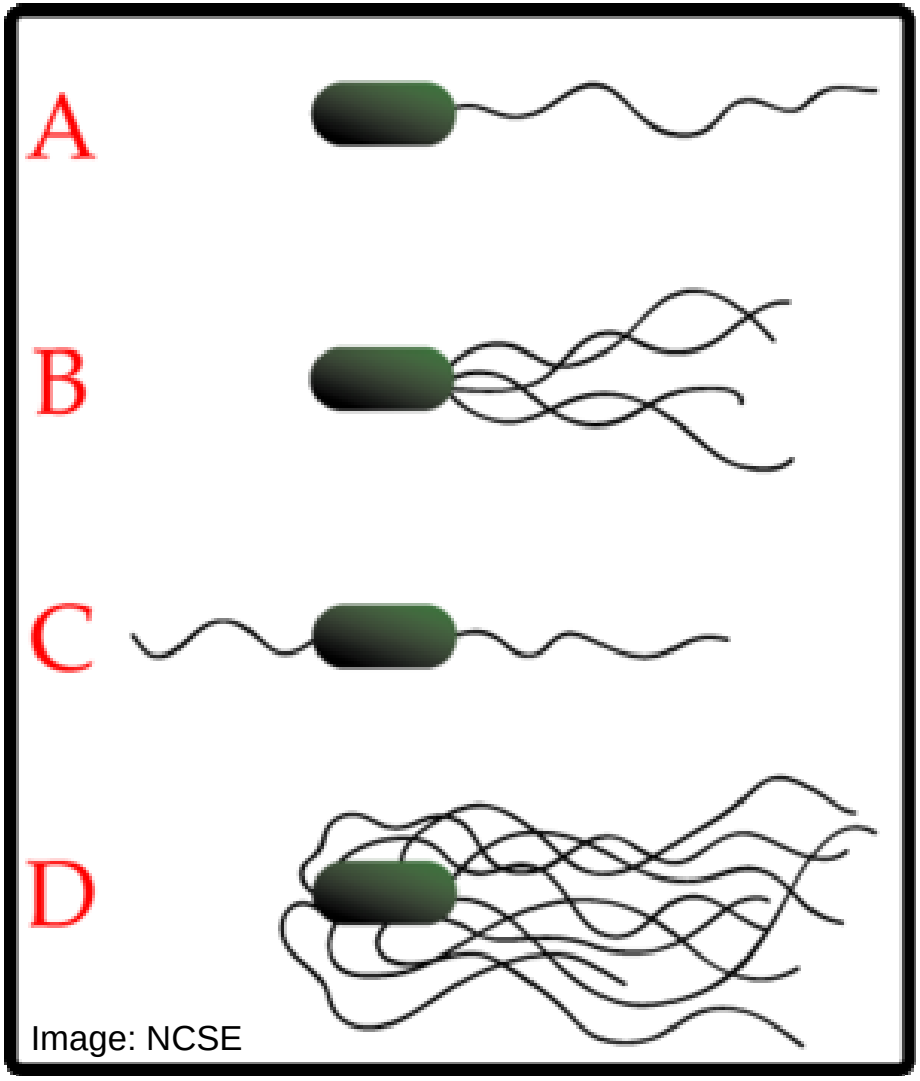
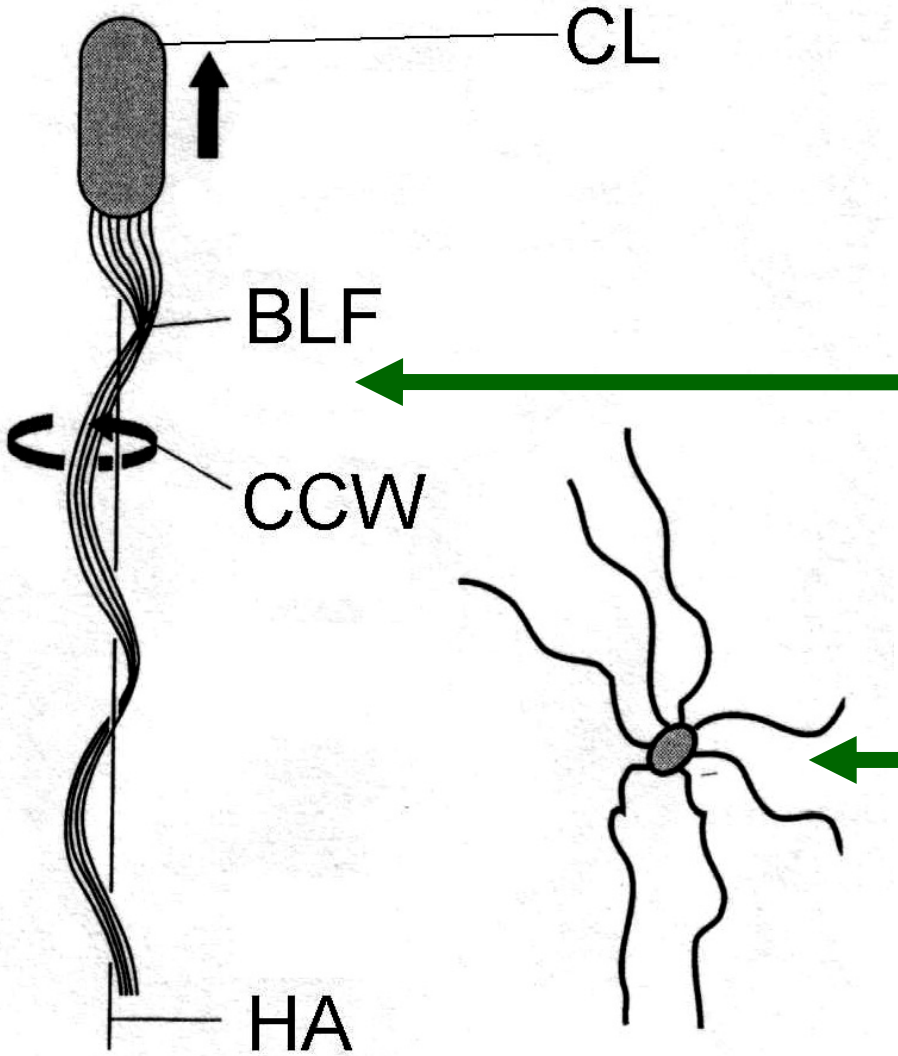


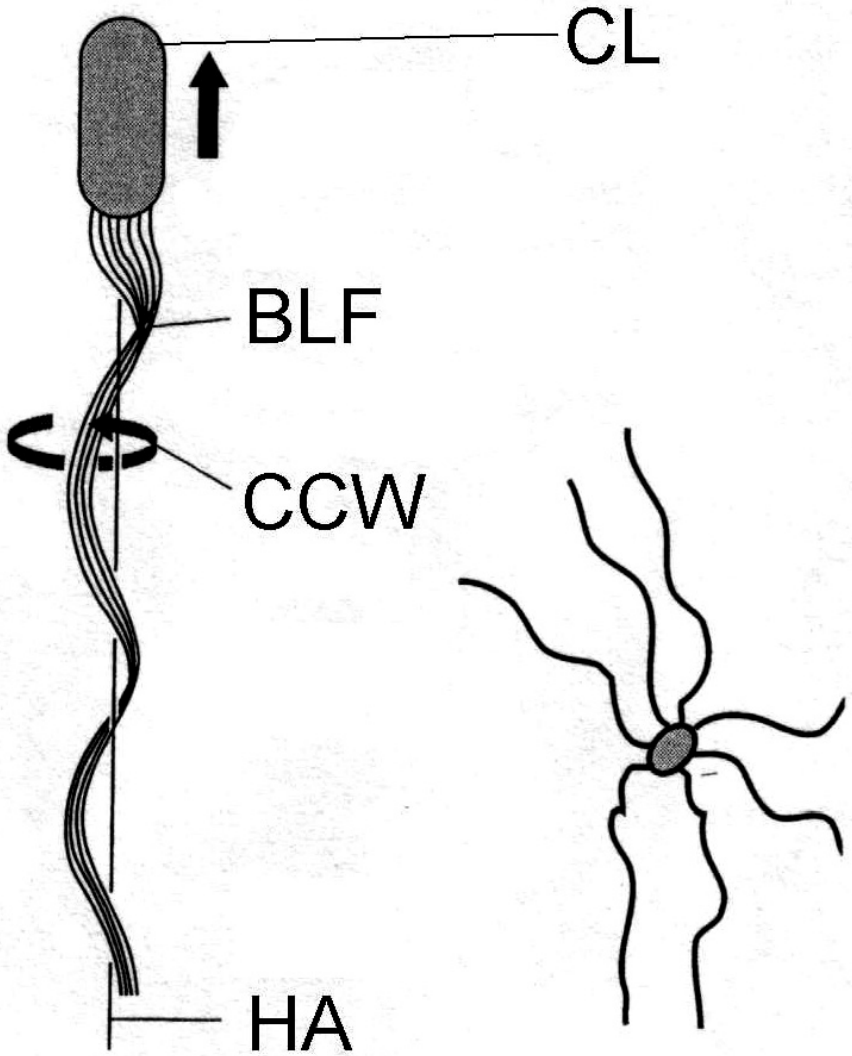
Bacterial Flagellum Arrangements



Effect of rotation with more flagella

Counter Clockwise:
- Structured motion
- Forward locomotion

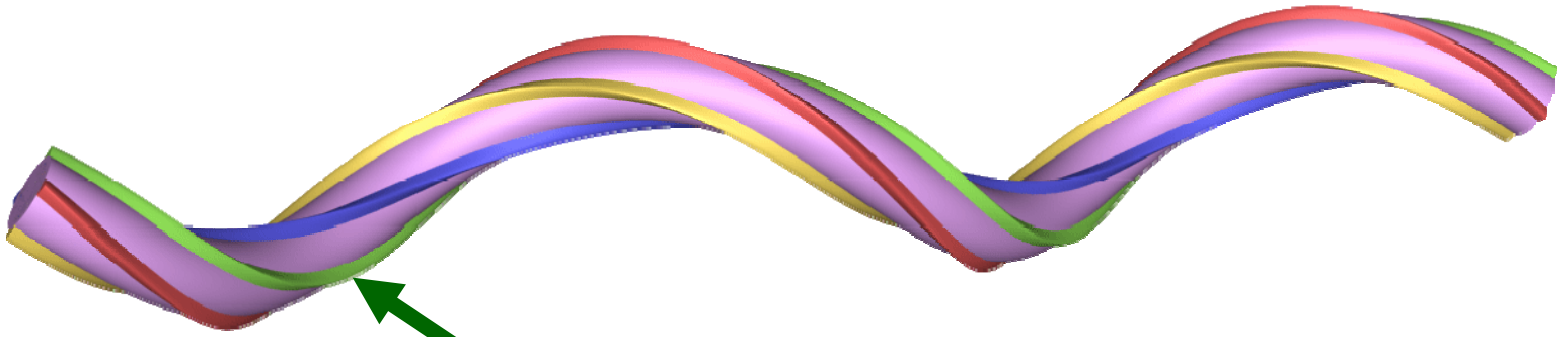
Clockwise:
- Messy motion
- Re-orientation



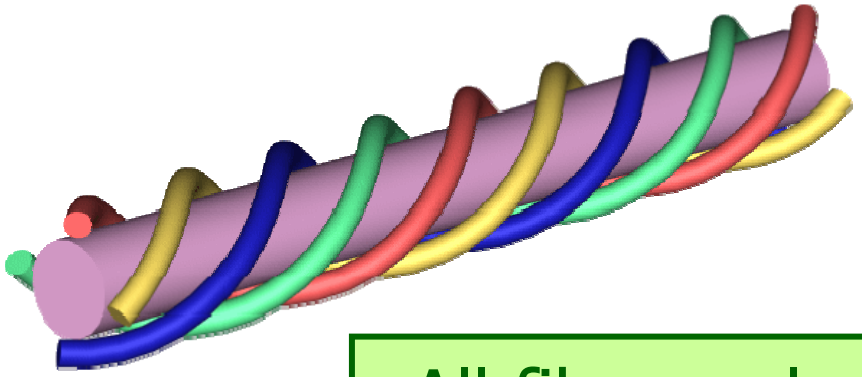
Effect of rotation with more flagella

Concentration food > when moving forward
→ Counter clockwise

Concentration food < when moving forward
→ Clockwise to change orientation



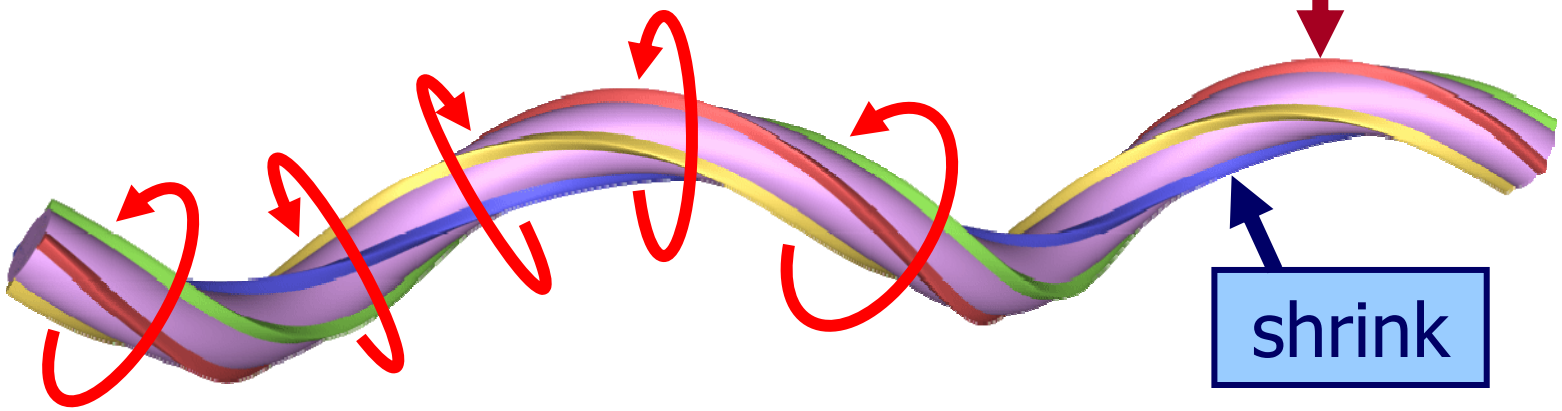
Fibers are wrapped around body



Motion theory:
Fibers can shrink & relax (like muscles)

All fibers relaxed

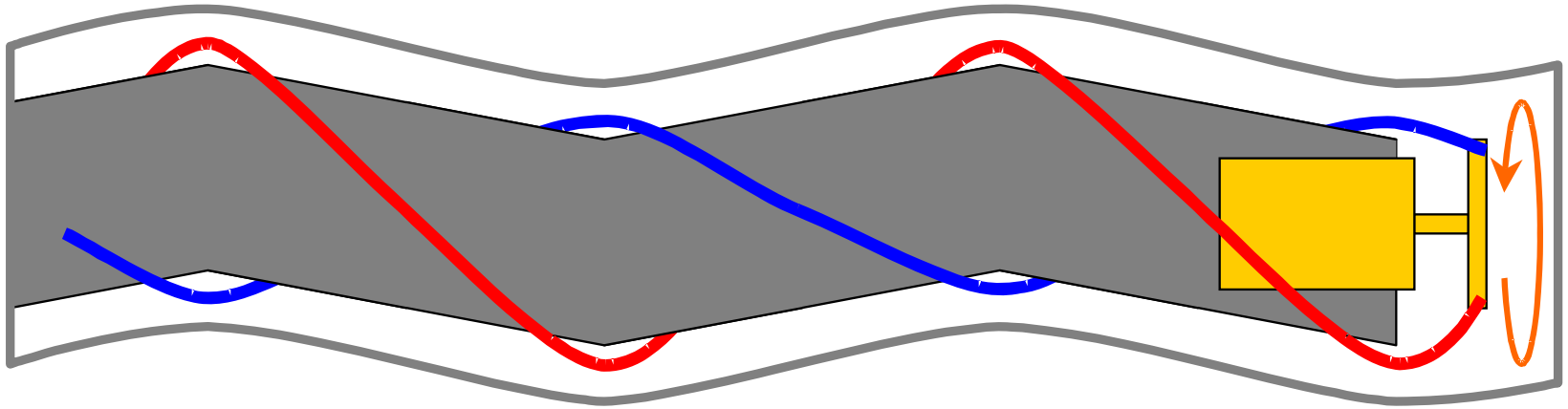
relax



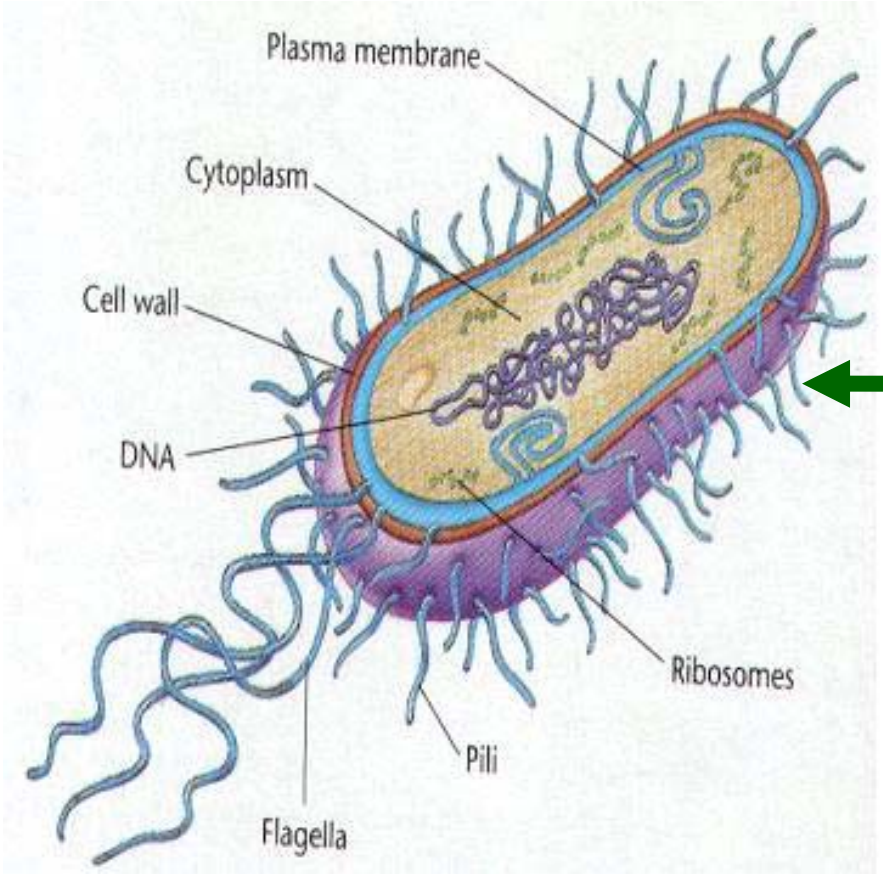
shrink

Fibers successively shrink & relax

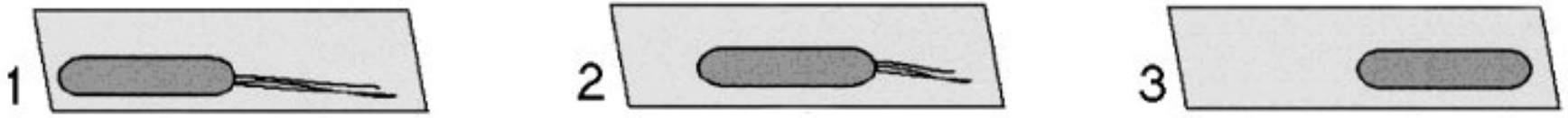
New motion theory:
Fibers are connected to rotary engine



Reaction torque makes body rotate (?)



Pili: "cables" that can be extended & retracted



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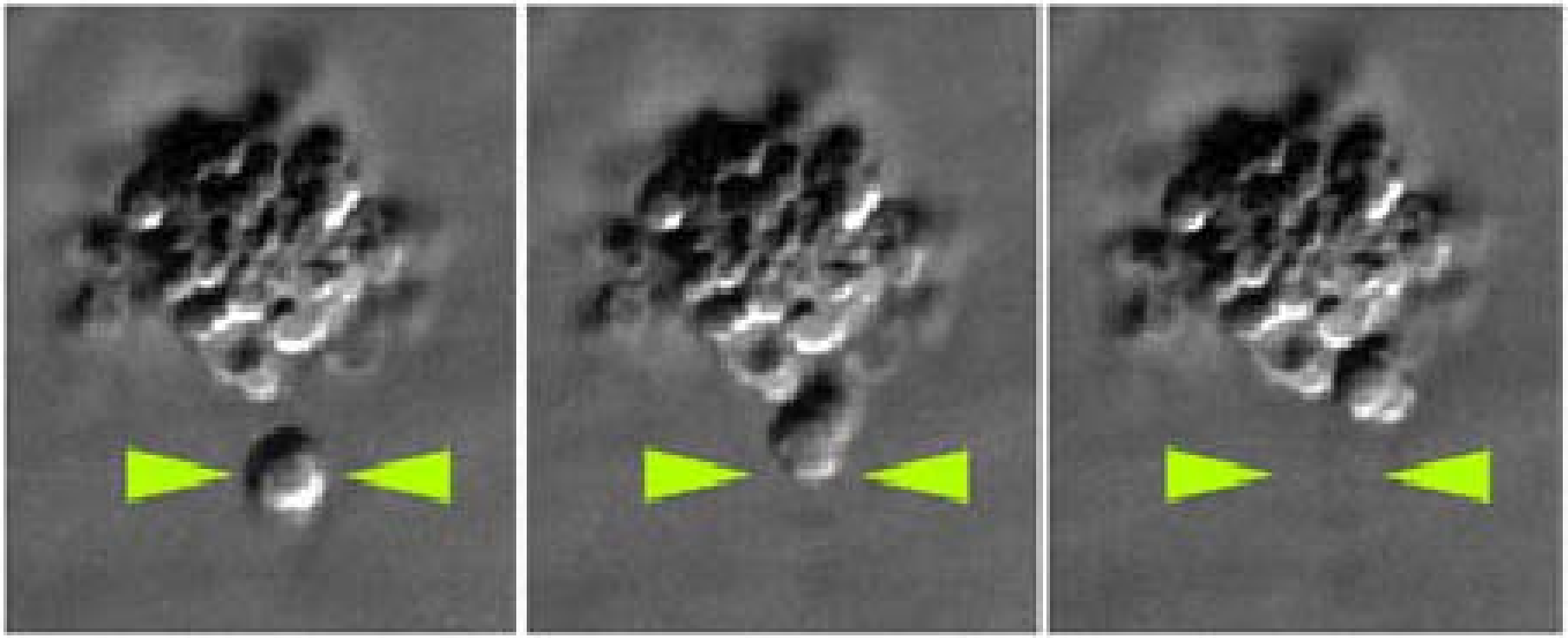
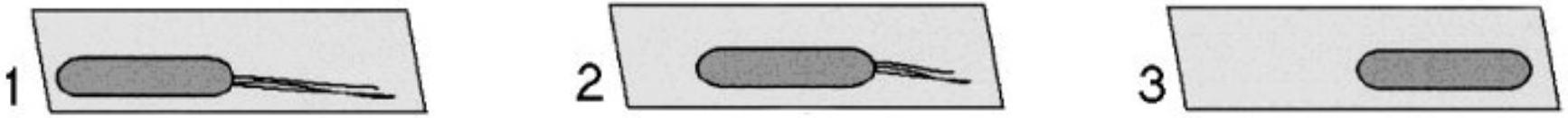
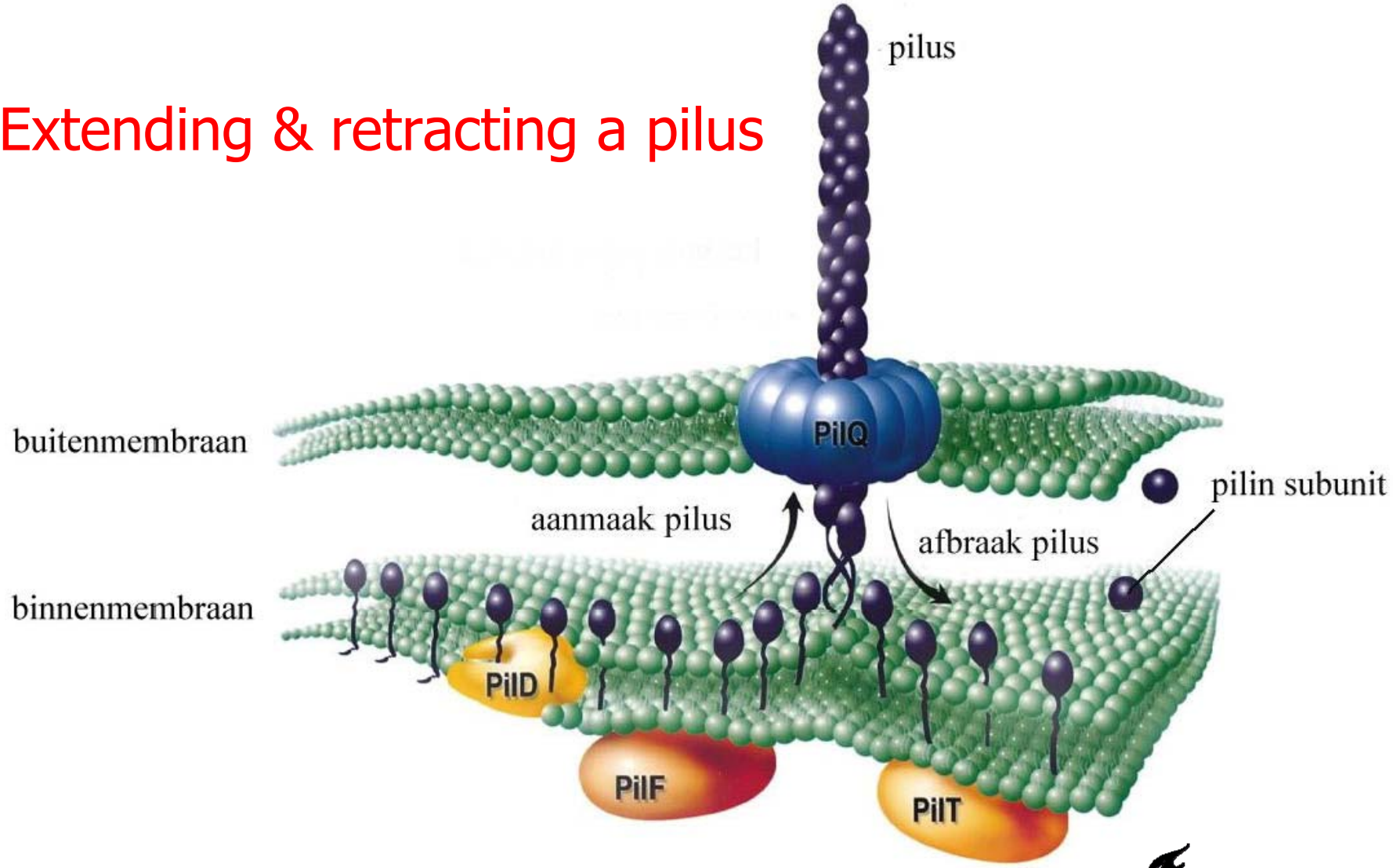


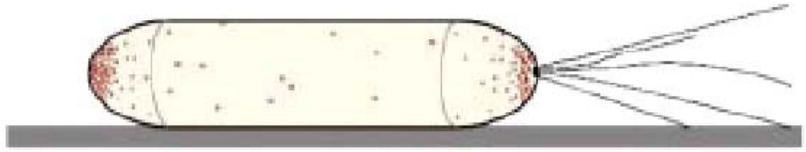
A bacteria uses pili to pull itself towards a colony



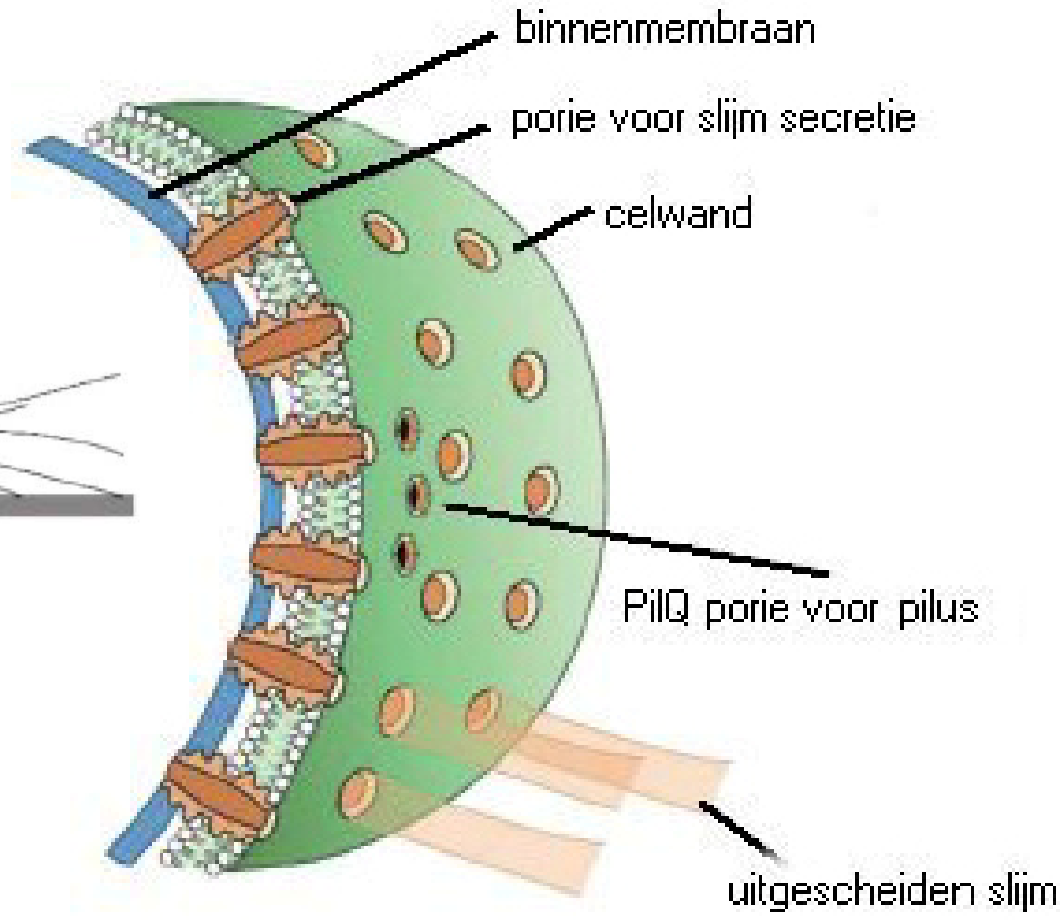
Extending & retracting a pilus

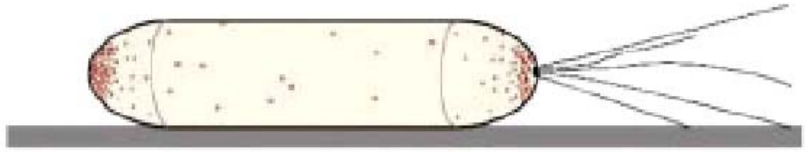


TU Delft

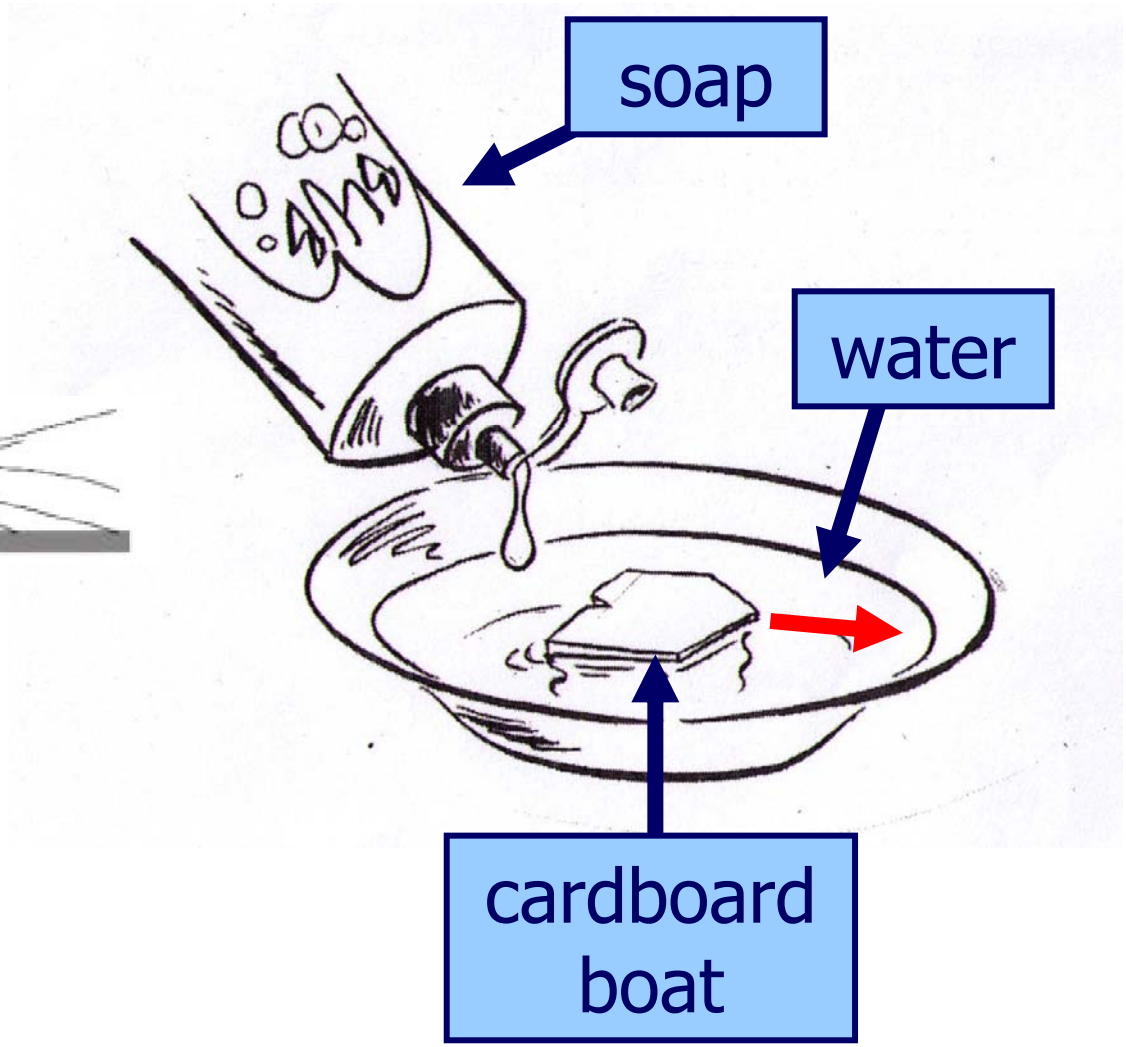


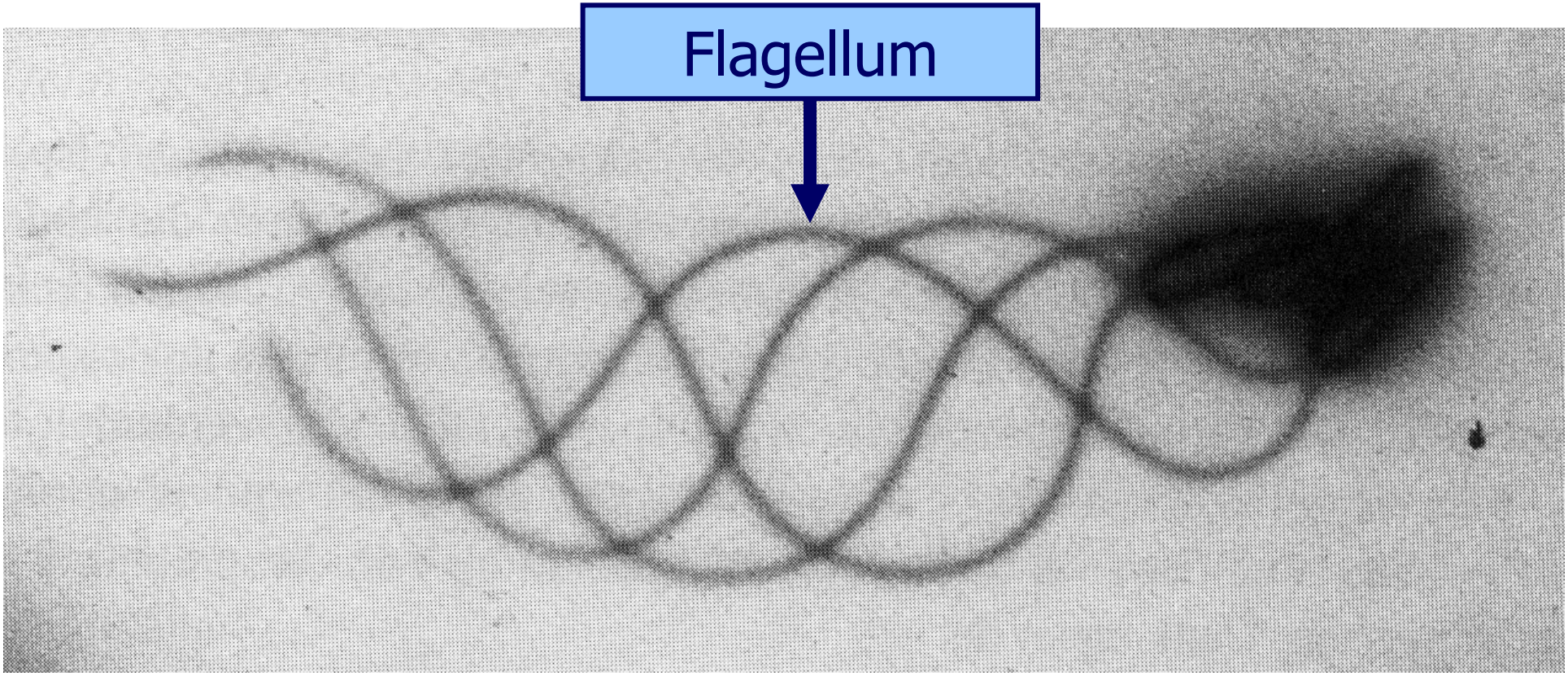
Volume displacement



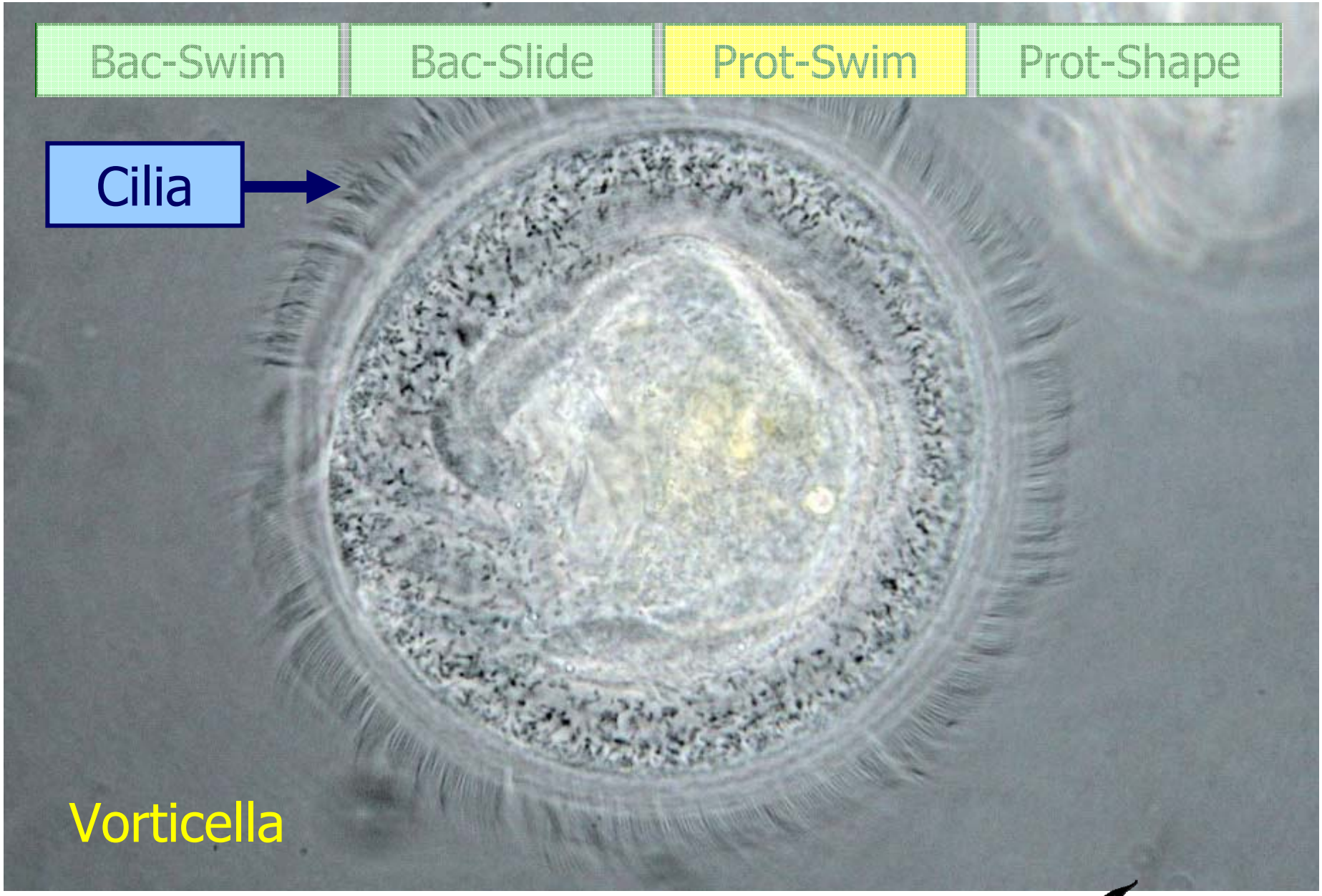


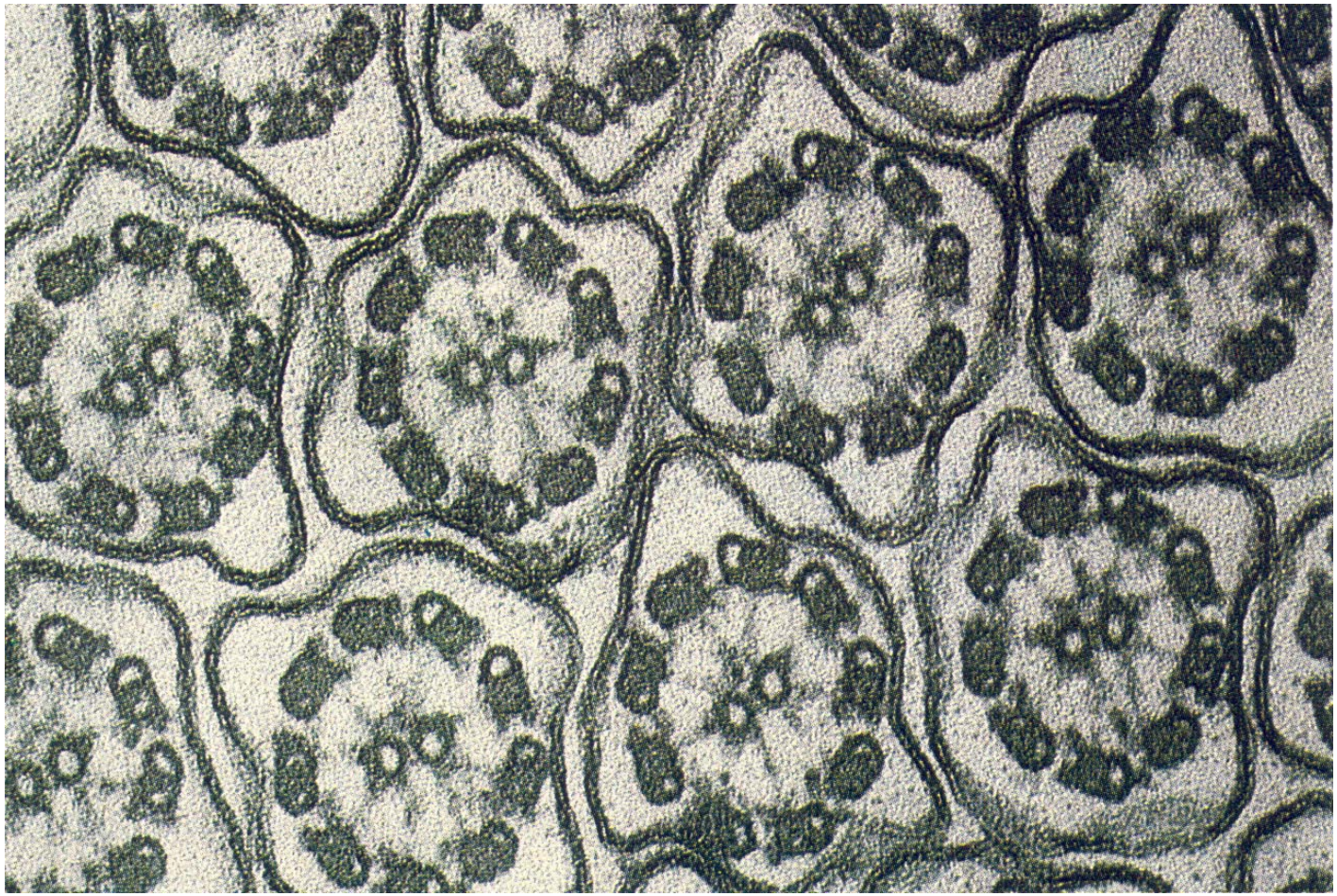
Volume displacement



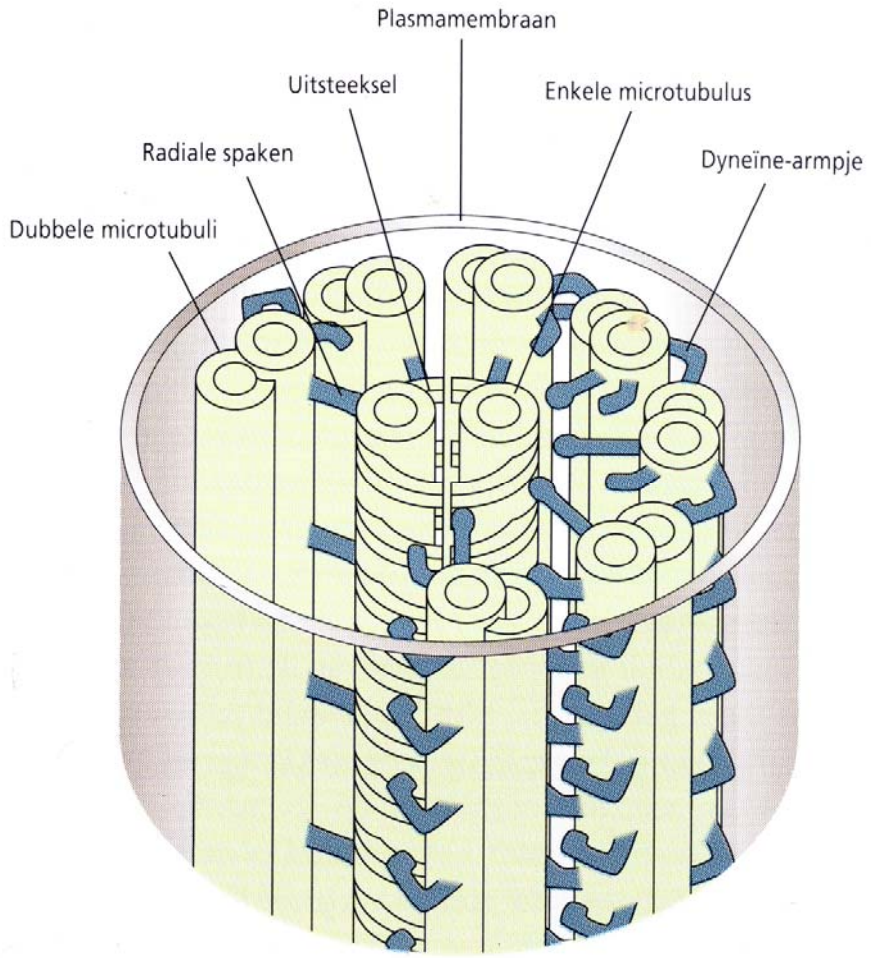


Sperm cell in 3 positions


Bac-Swim
Bac-Slide
Prot-Swim
Prot-Shape
Cilia
Vorticella



Structure of flagellum & cilia (identical)



Structure of flagellum & cilia (identical)

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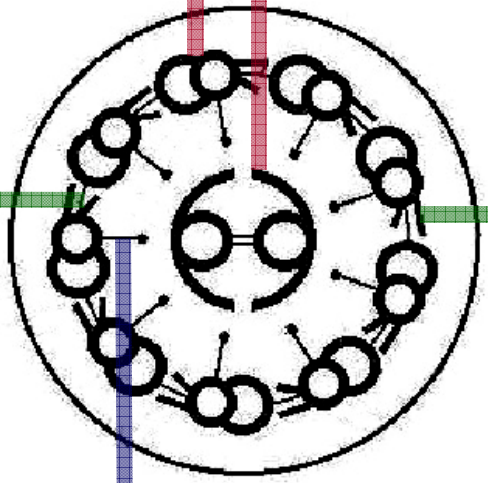
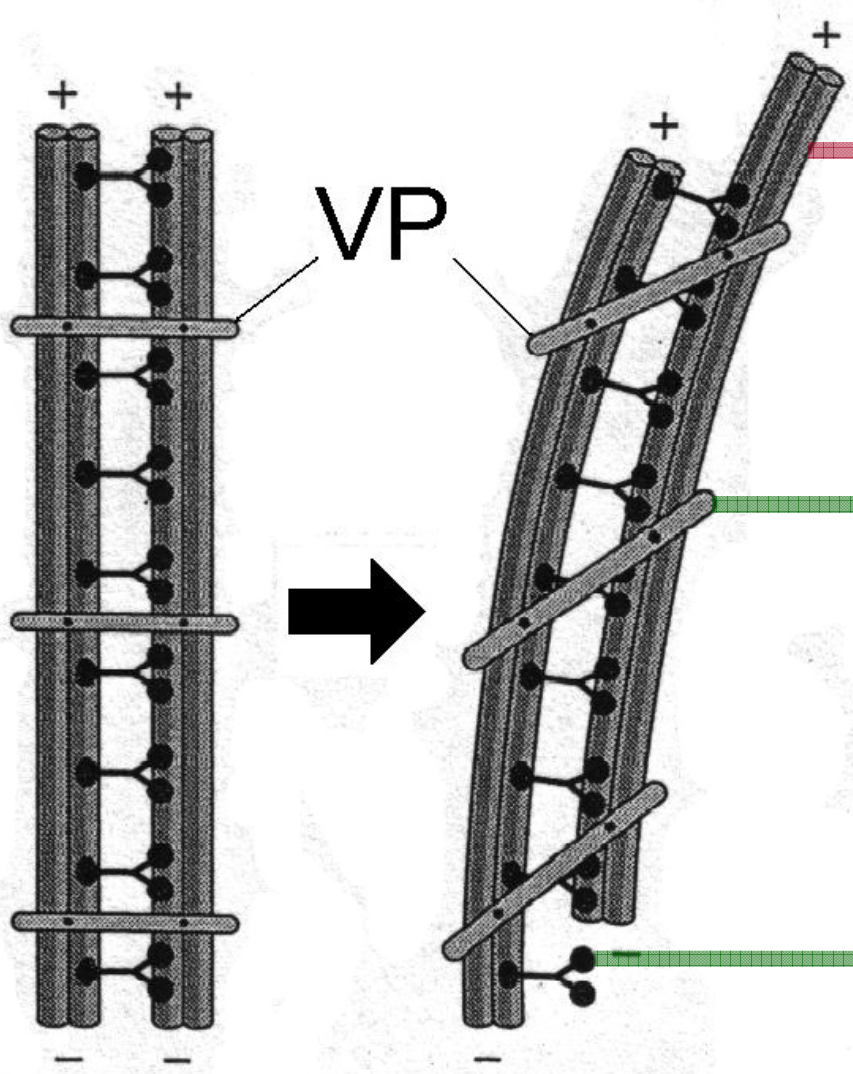
Microtubuli
(bendable tubes)

"Nexine" Links
(flexible tube-
connectors)



"Dyneïne" Arms
(linear motors)

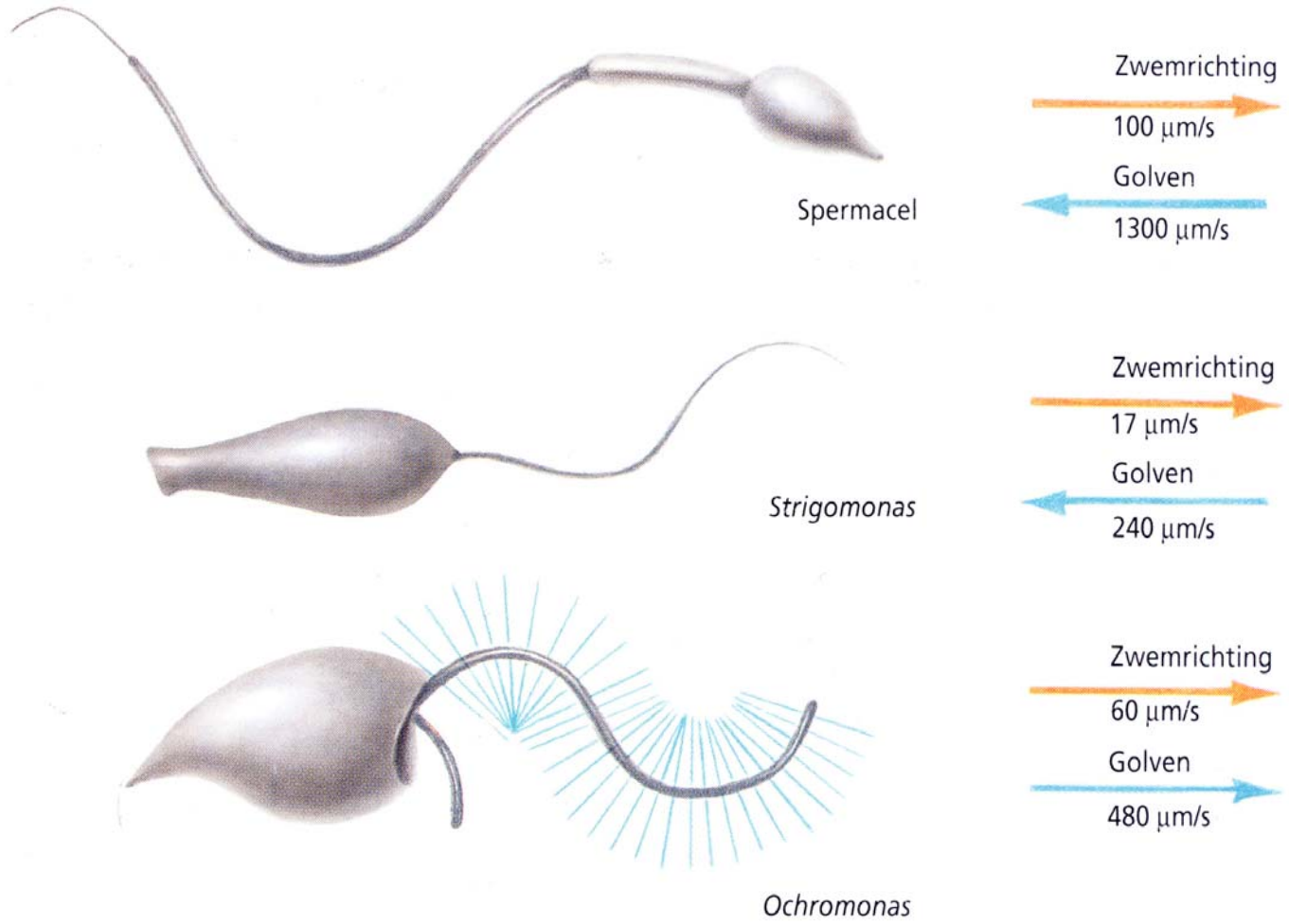
Radial Spokes
(sliding distance holders)



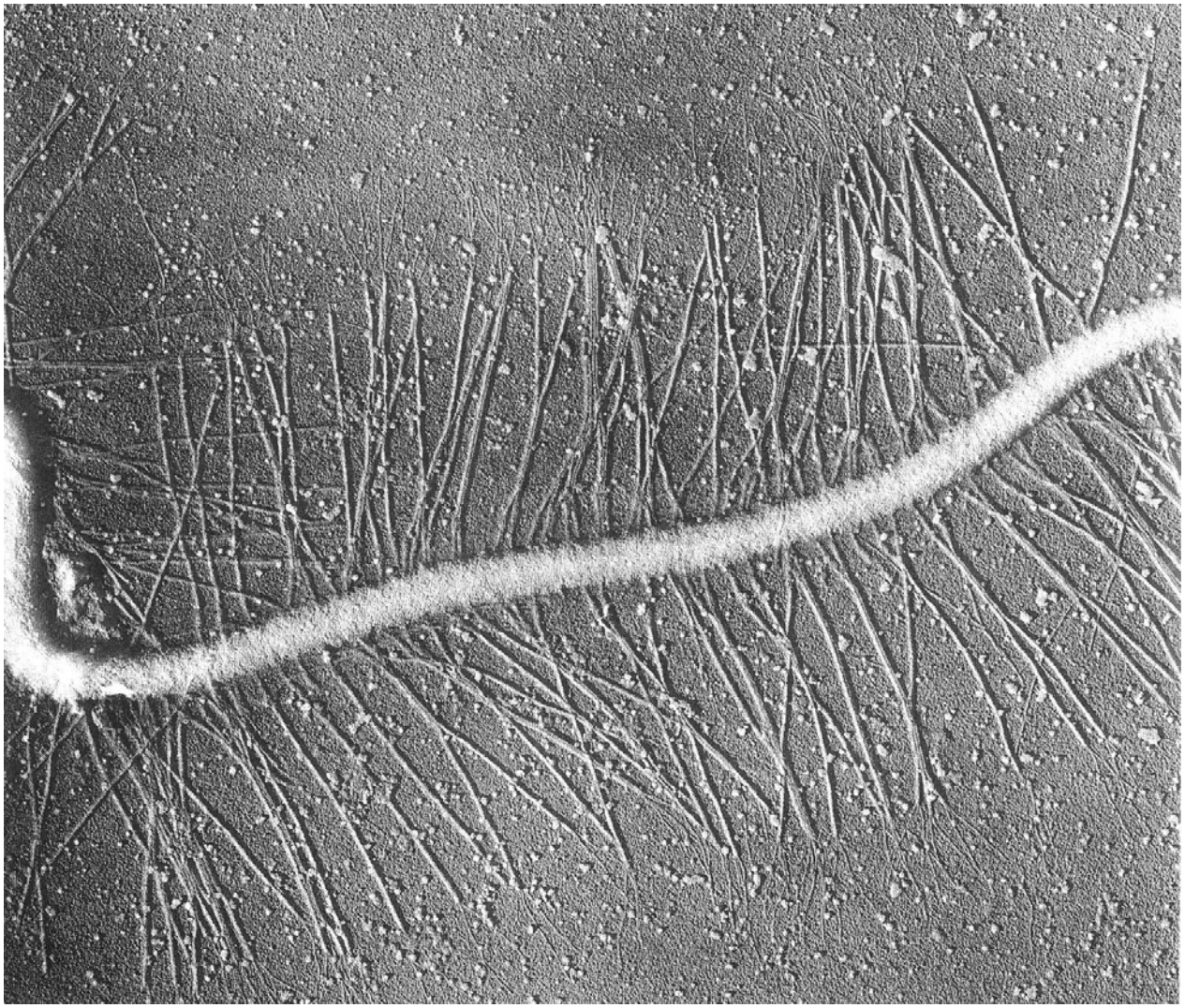
Microtubuli (bendable tubes)

"Nexine" Links (flexible tube-connectors)

"Dyneïne" Arms (linear motors)

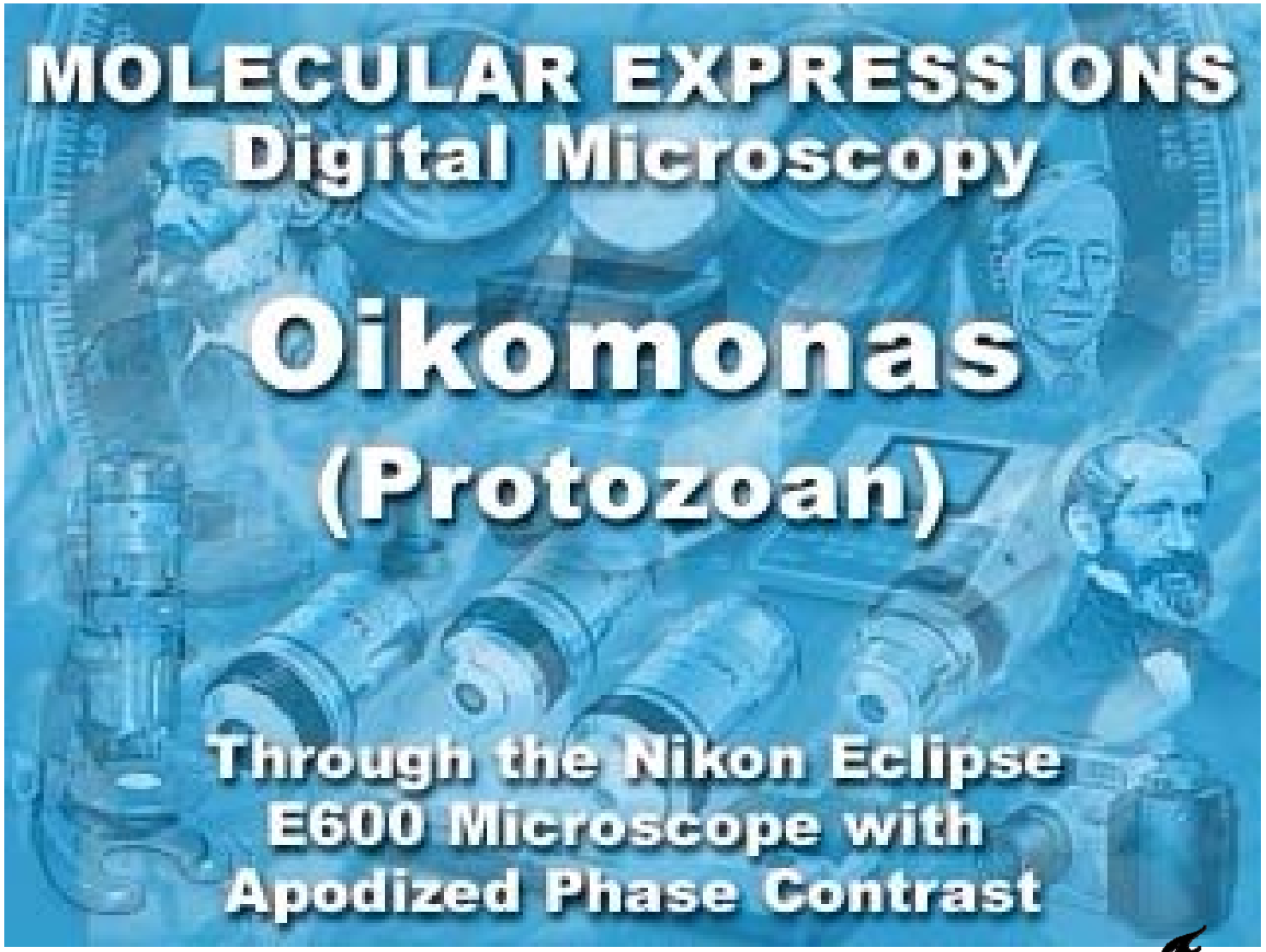


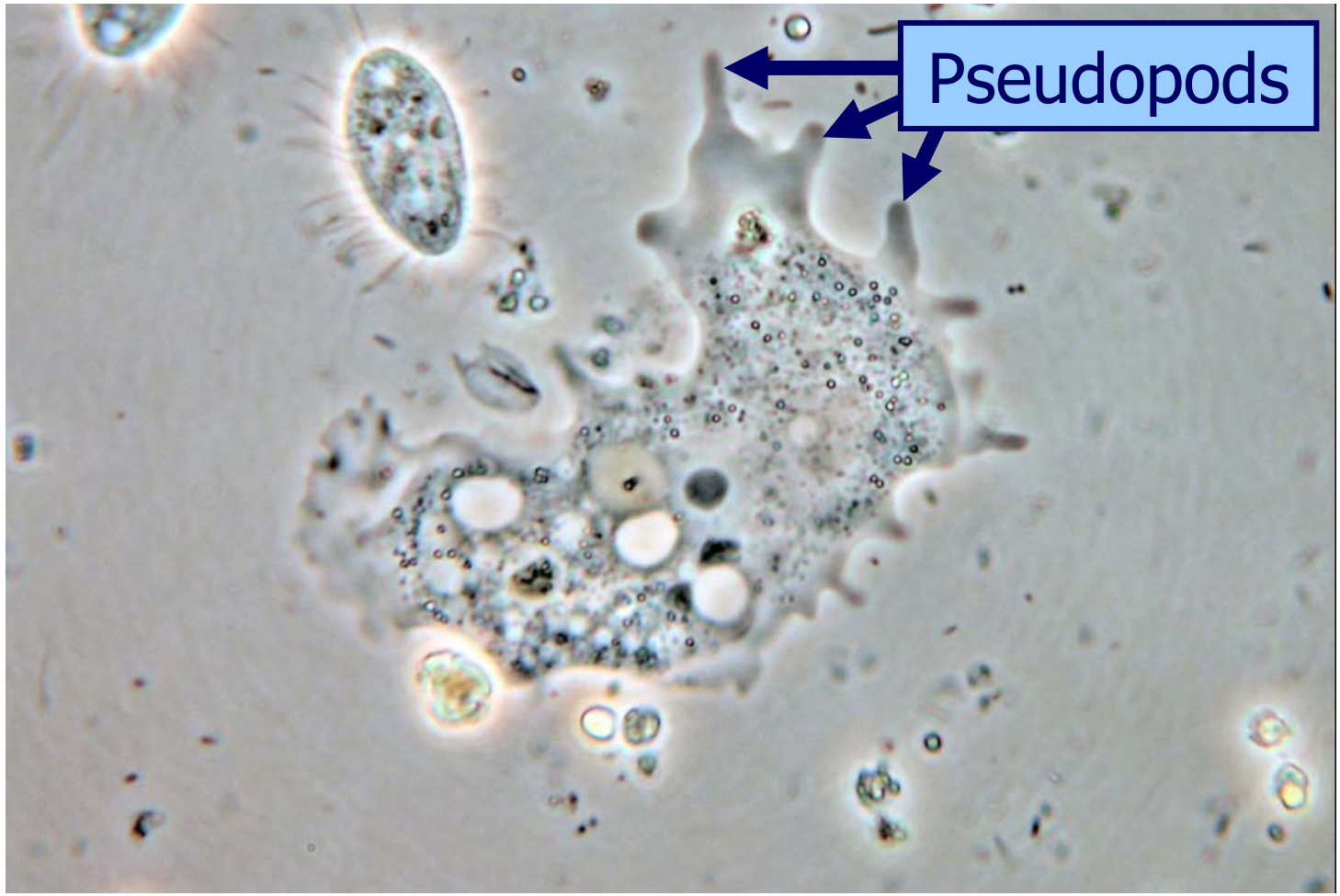
Flagellum configurations




Nikon MicroscopyU
Digital Video Gallery
Euplotes
(Protozoan)
Through the Nikon Eclipse
E600 Microscope with
Apodized Phase Contrast

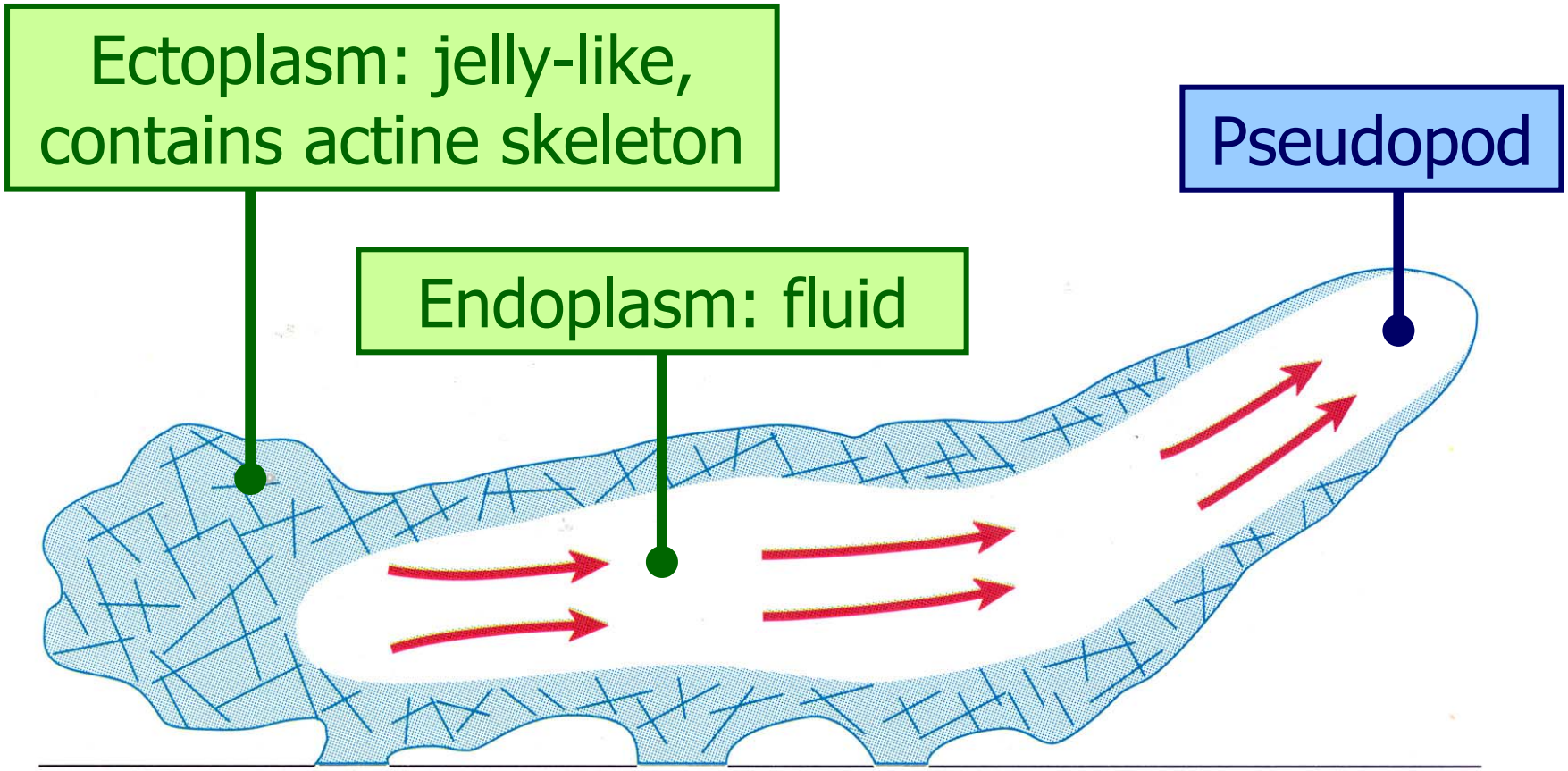

Nikon MicroscopyU
Digital Video Gallery
Paramecium
(Protozoan)
Through the Nikon Eclipse
E600 Microscope with
Apodized Phase Contrast


MOLECULAR EXPRESSIONS
Digital Microscopy
Oikomonas
(Protozoan)
Through the Nikon Eclipse
E600 Microscope with
Apodized Phase Contrast

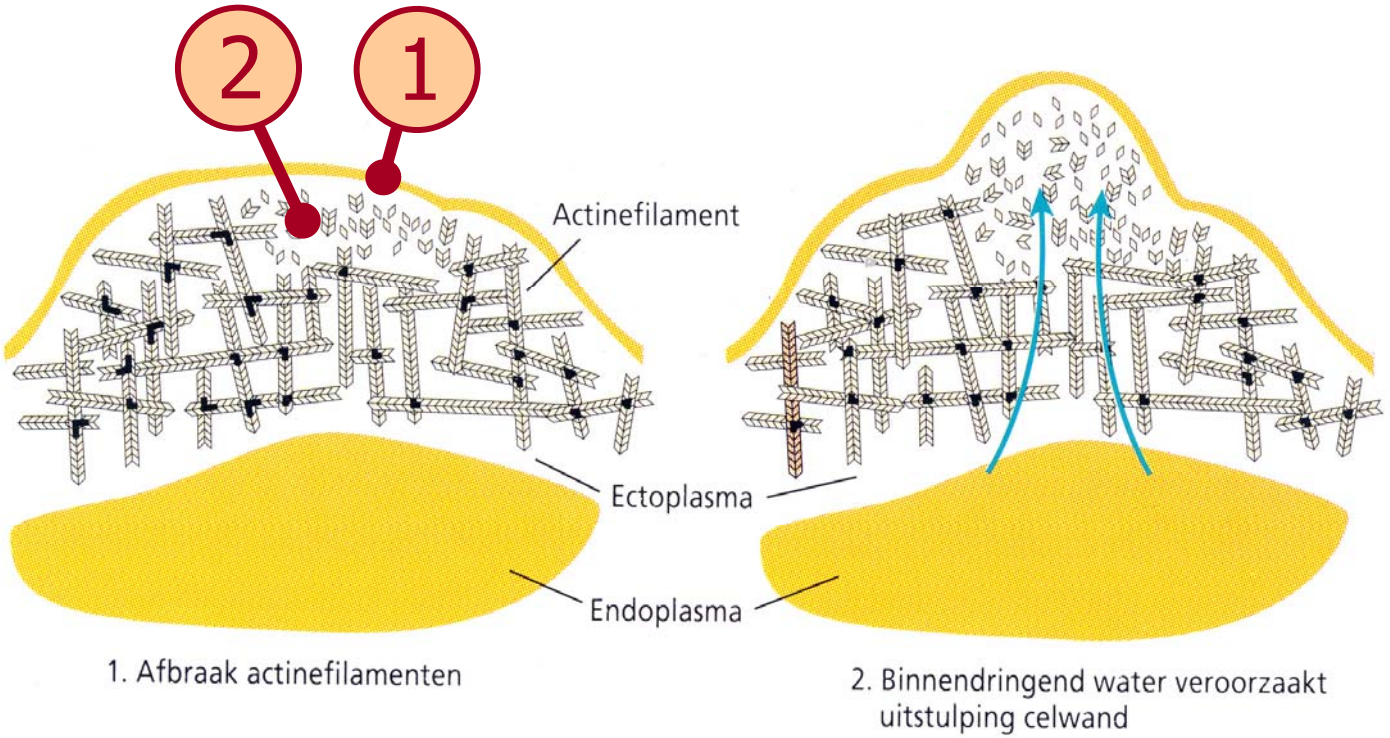


Amoeba

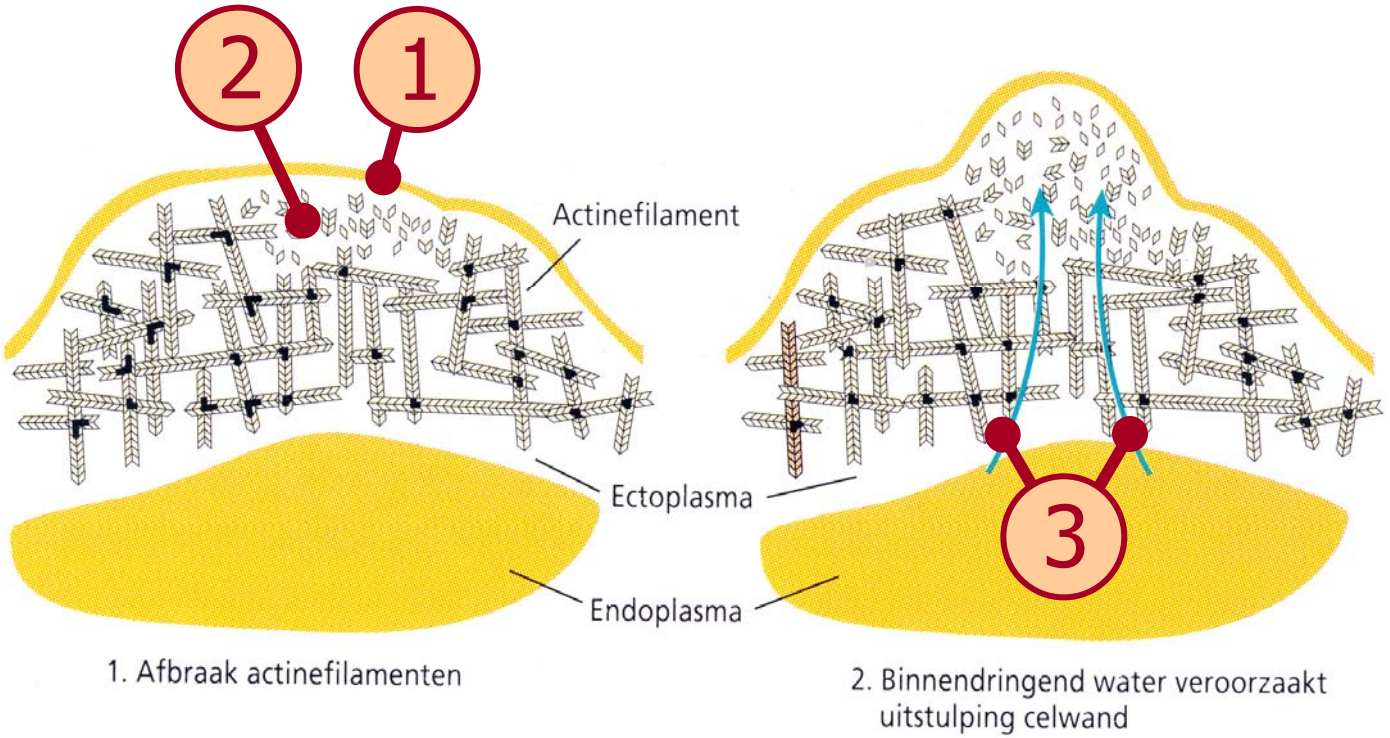
TU Delft


Ectoplasm: jelly-like, contains actine skeleton
Pseudopod
Endoplasm: fluid

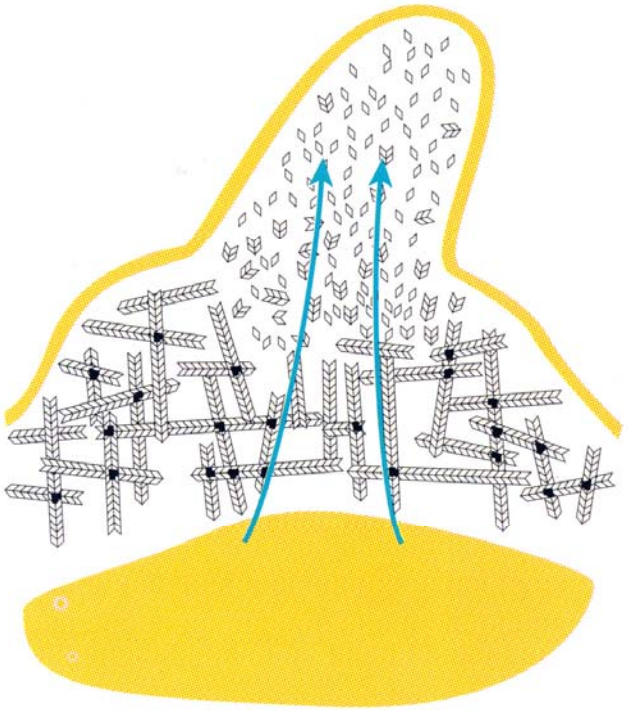
Amoeba



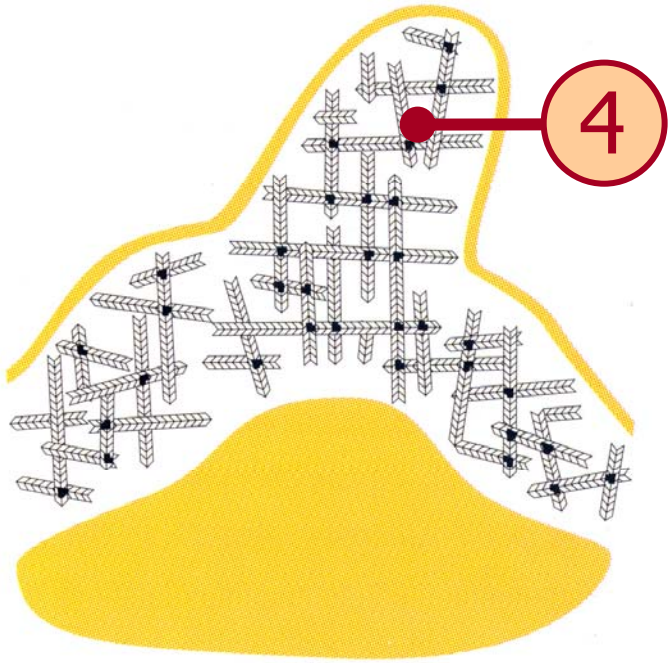
1. Anti-body activates receptor in cell membrane
2. Receptor makes actin skeleton fall apart in small particles.



3. Particles initiate osmosis: water from endoplasm flows towards higher particle concentration, creating a pseudopod



3. Pseudopodium bereikt zijn definitieve grootte



4. Ontstaan van nieuwe actinefilamenten.

4. Receptor stops working, skeleton is constructed again, fixing shape pseudopod & preventing water to flow back


Nikon MicroscopyU
Digital Video Gallery
Amoeba
(Protozoan)
Through the Nikon Eclipse
E600 Microscope with
Apodized Phase Contrast


Nikon MicroscopyU
Digital Video Gallery
Amoeba
(Protozoan)
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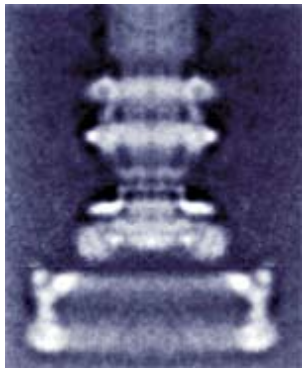
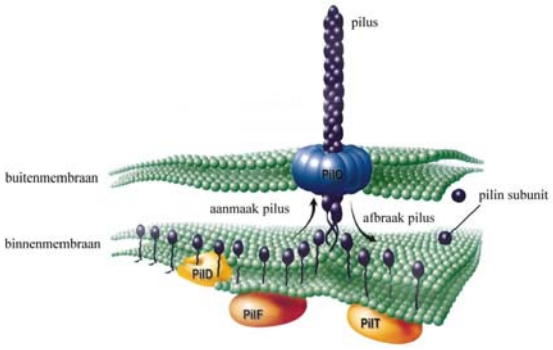
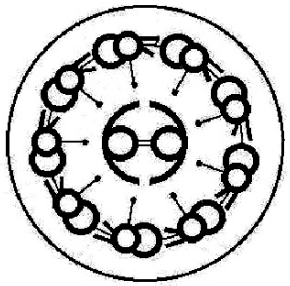
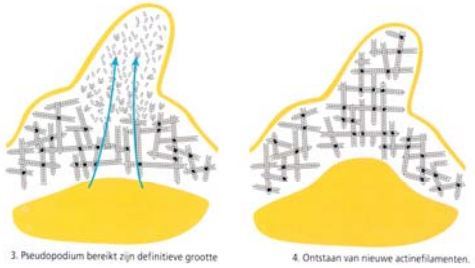
E600 Microscope with
Apodized Phase Contrast

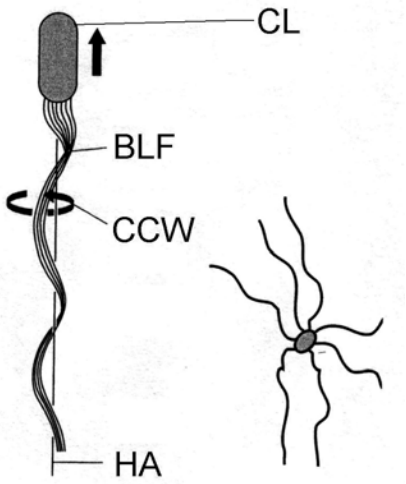
Bac-Swim	Bac-Slide	Prot-Swim	Prot-Shape

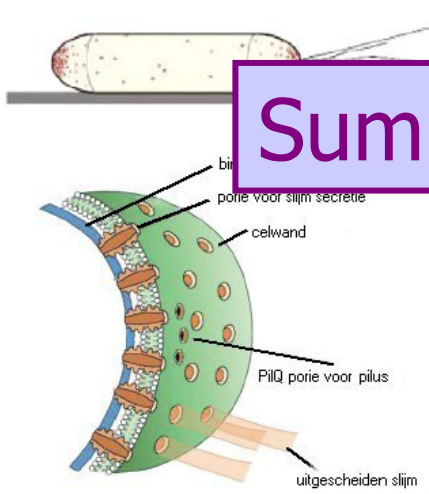




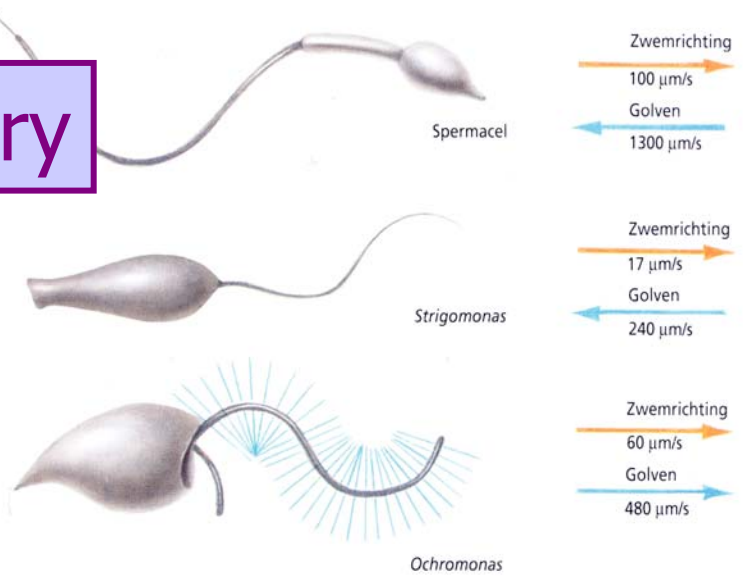


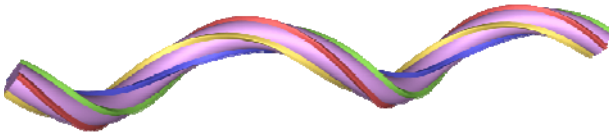






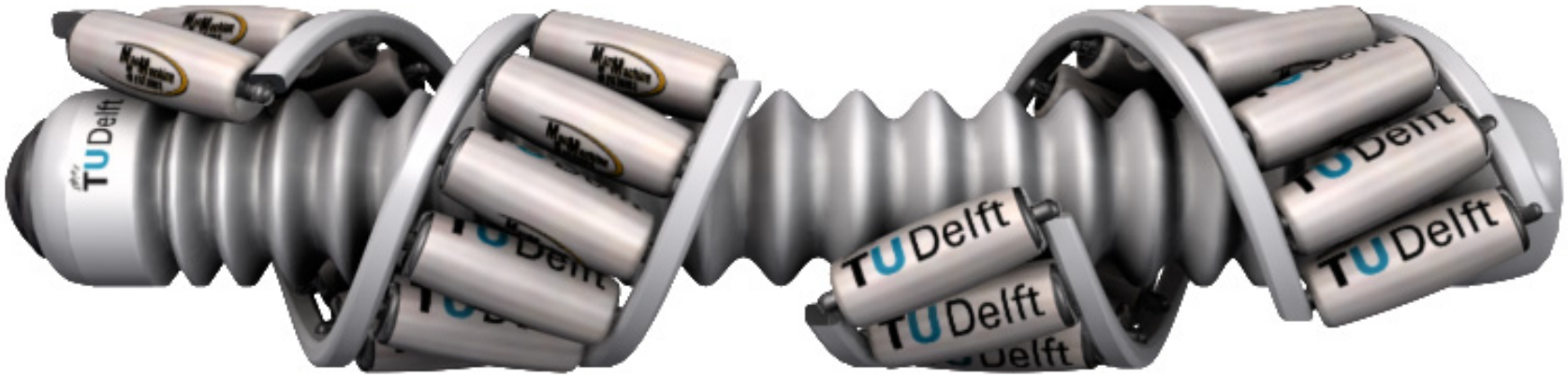
Summary





TU Delft

Bac-Swim	Bac-Slide	Prot-Swim	Prot-Shape



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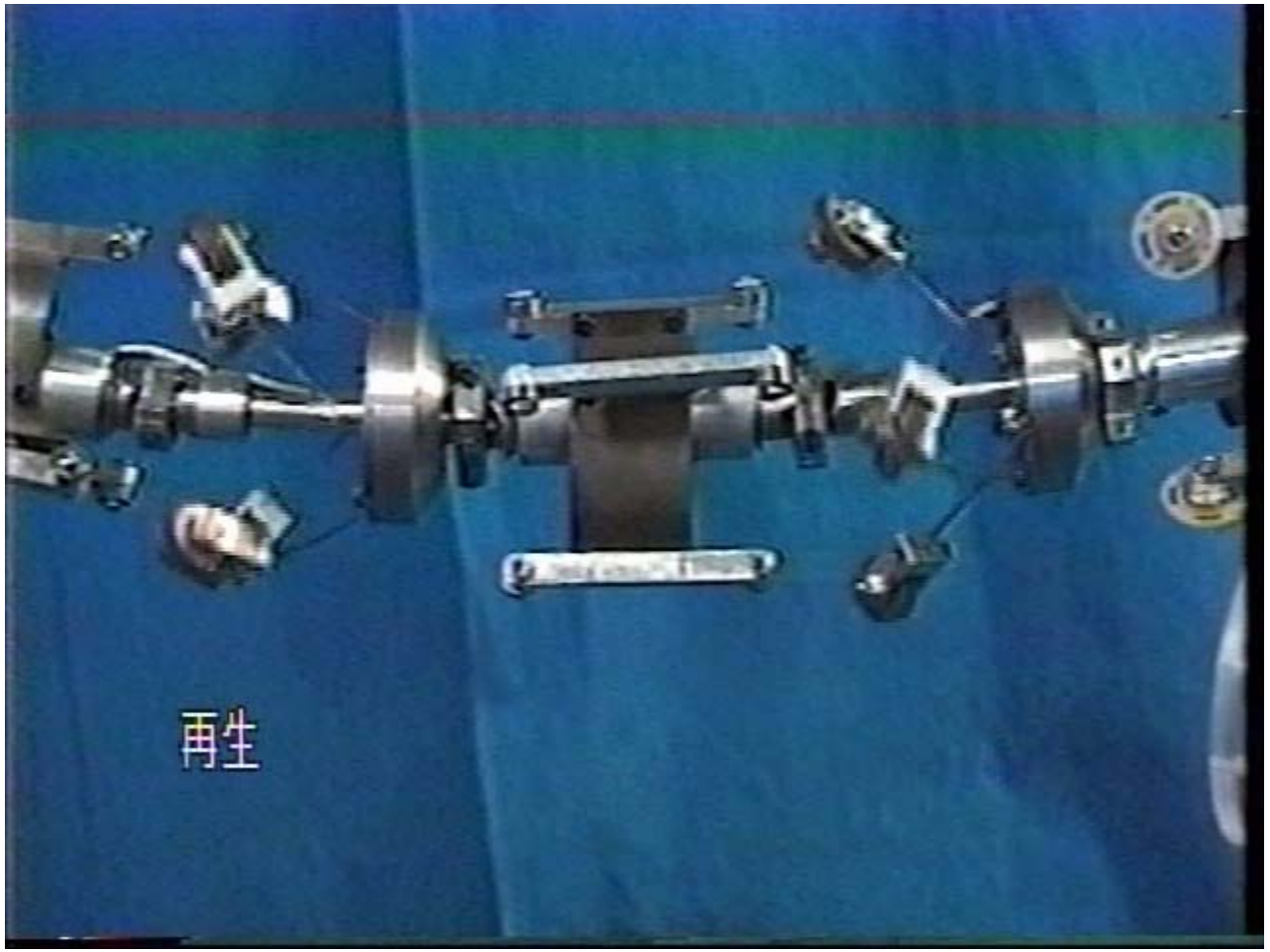
Bac-Swim	Bac-Slide	Prot-Swim	Prot-Shape



Interesting References

Exploring Biomechanics
R. McNeill Alexander
The Scientific American Library, 1992

Voortbeweging bij Eéncelligen
P. Tjon Pon Fong, A. Smeele
Stage Rapport, 2004

Design Remarks

Reason! Explain why you did it, explain the reasoning behind your design.

Limit yourself: do not try to solve everything in 2 months, limit your assignment.

Focus on novel method/mechanism, not on standard extra tools like camera's etc.

Check Bio-Inspired Design_Assessment.doc!

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