BIOLOGI SEL

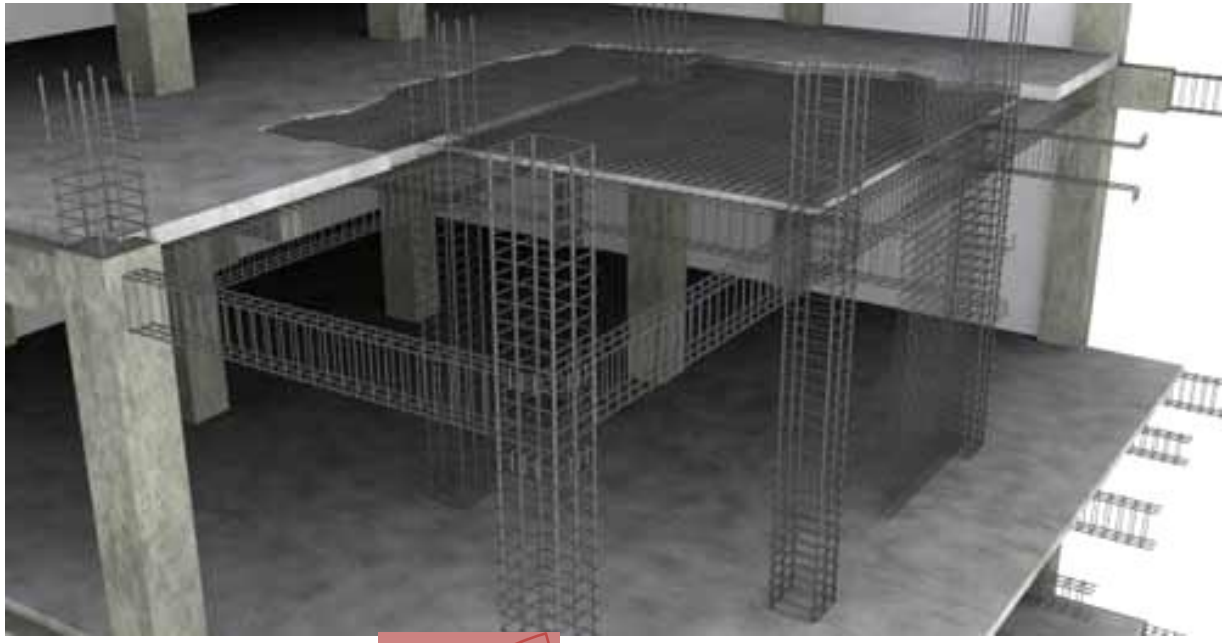
Chapter X

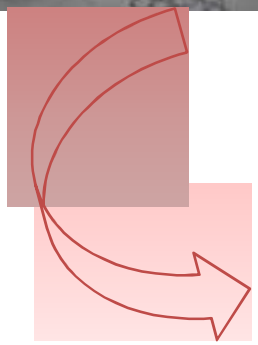
SITOSKELETON, SENTROSOM, FLAGEL & SILIA, SAMBUNGAN ANTAR SEL

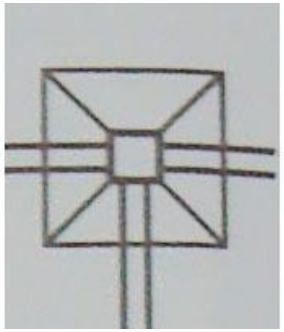
Husni Mubarok, S.Pd., M.Si.

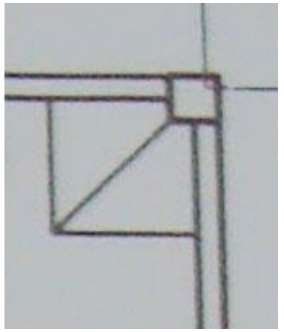
APA ITU SITOSKELETON..??

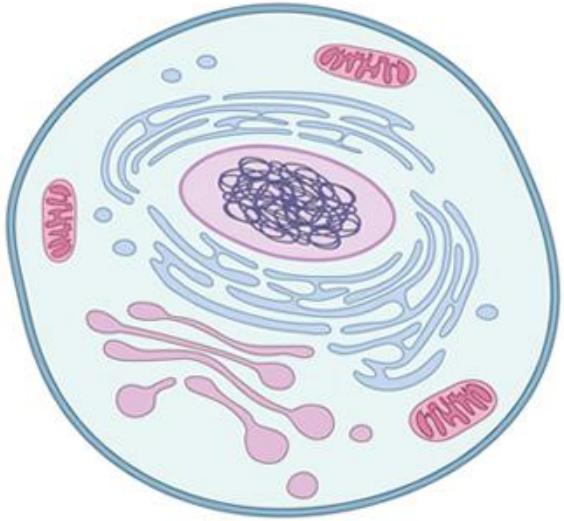
ANALOGI











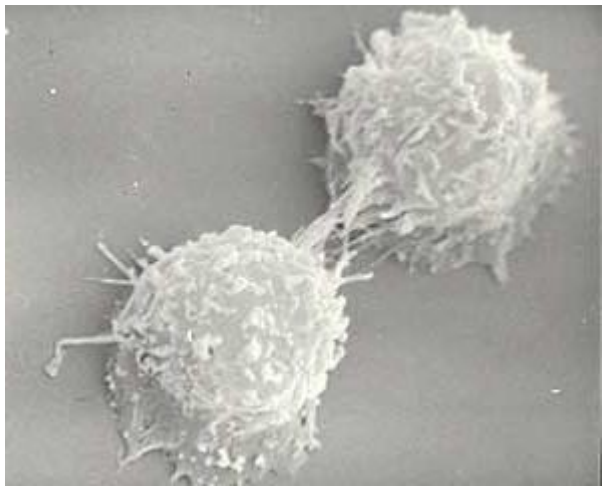
SITO = SEL

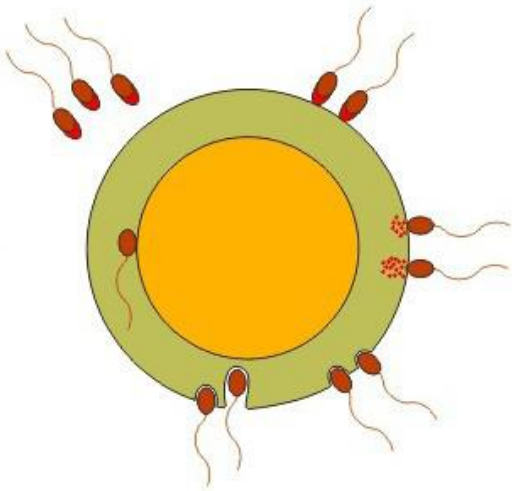
SKELETON = RANGKA

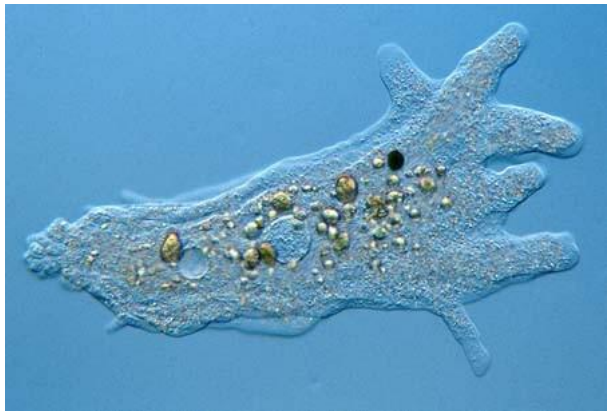
SITOSKELETON = KERANGKA SEL

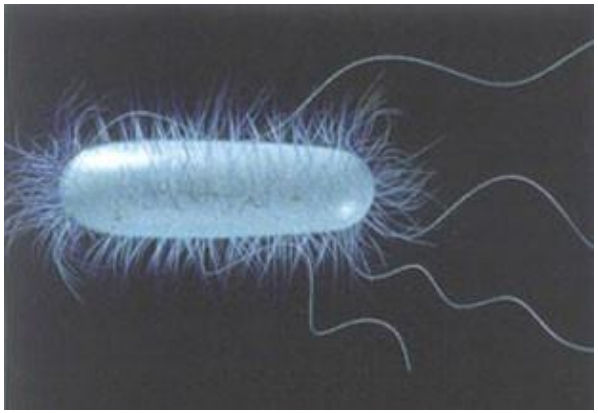
Eukaryotic cells are capable of changing their shape, moving organelles, moving from place to place. This requires **network of protein filaments placed in the cytoplasm and known as the Cytoskeleton**

Bagaimana Sel Prokariotik?



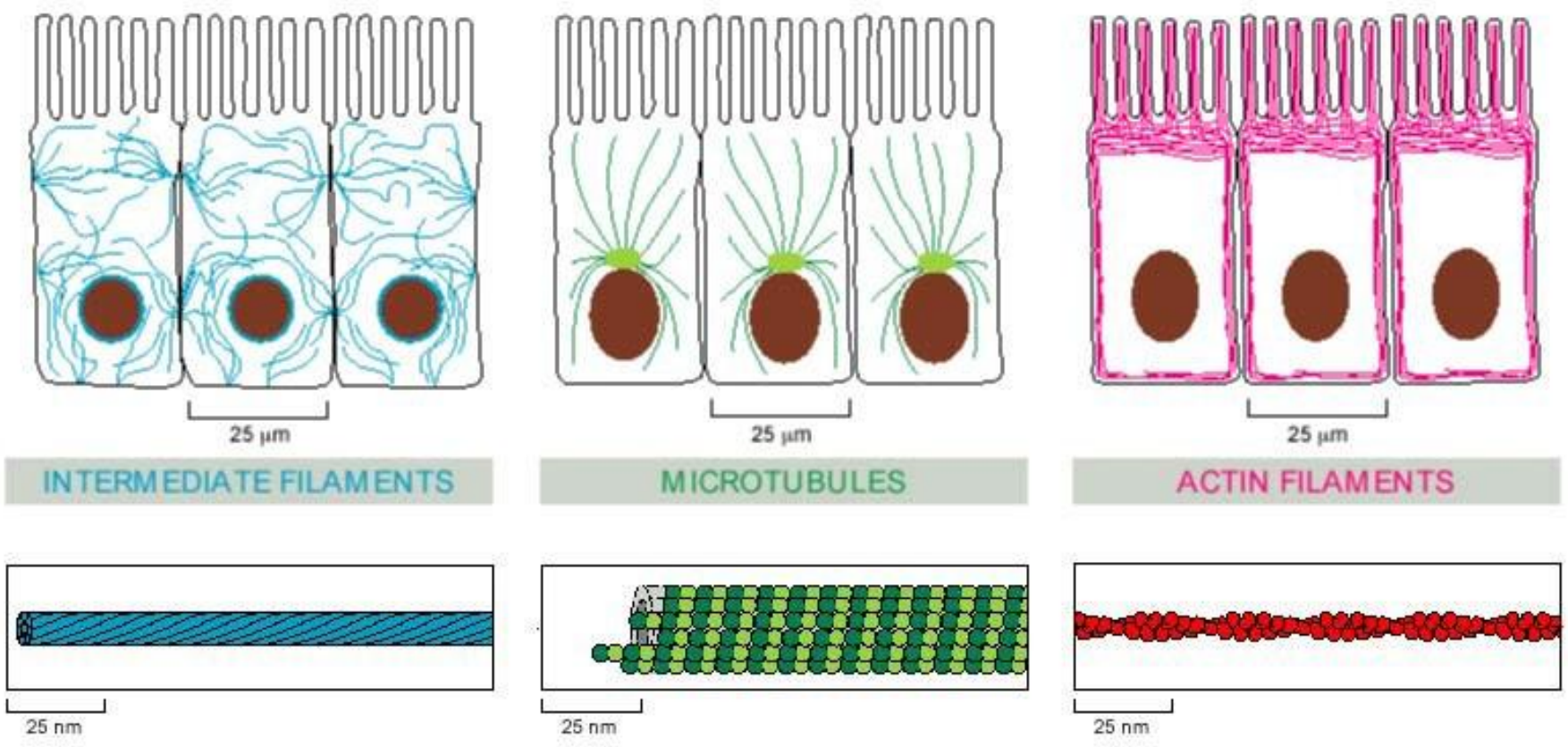


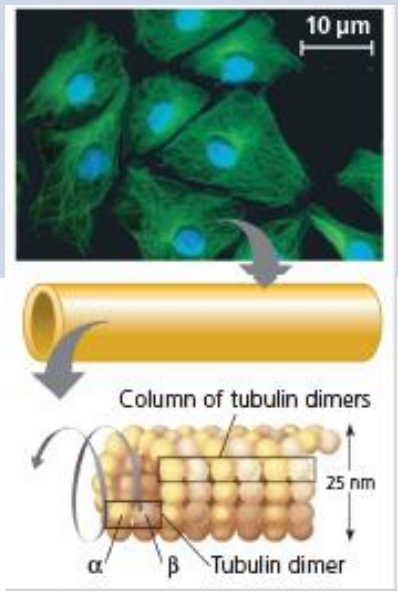
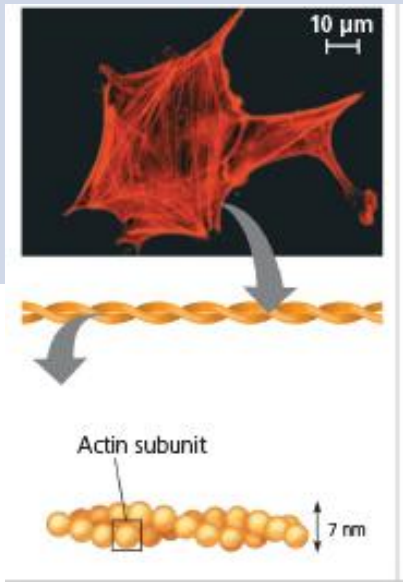
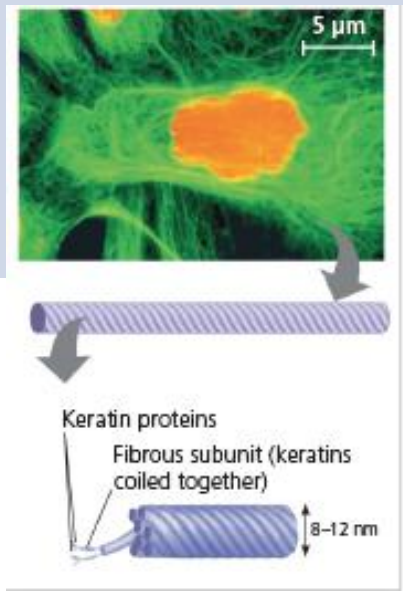




3 Kelas Elemen Sitoskeleton

- **Microtubules**……(25 nm in diameter)
- **Actin Filaments (Microfilaments)**….(7 nm)
- **Intermediate Filaments**……..(10 nm)



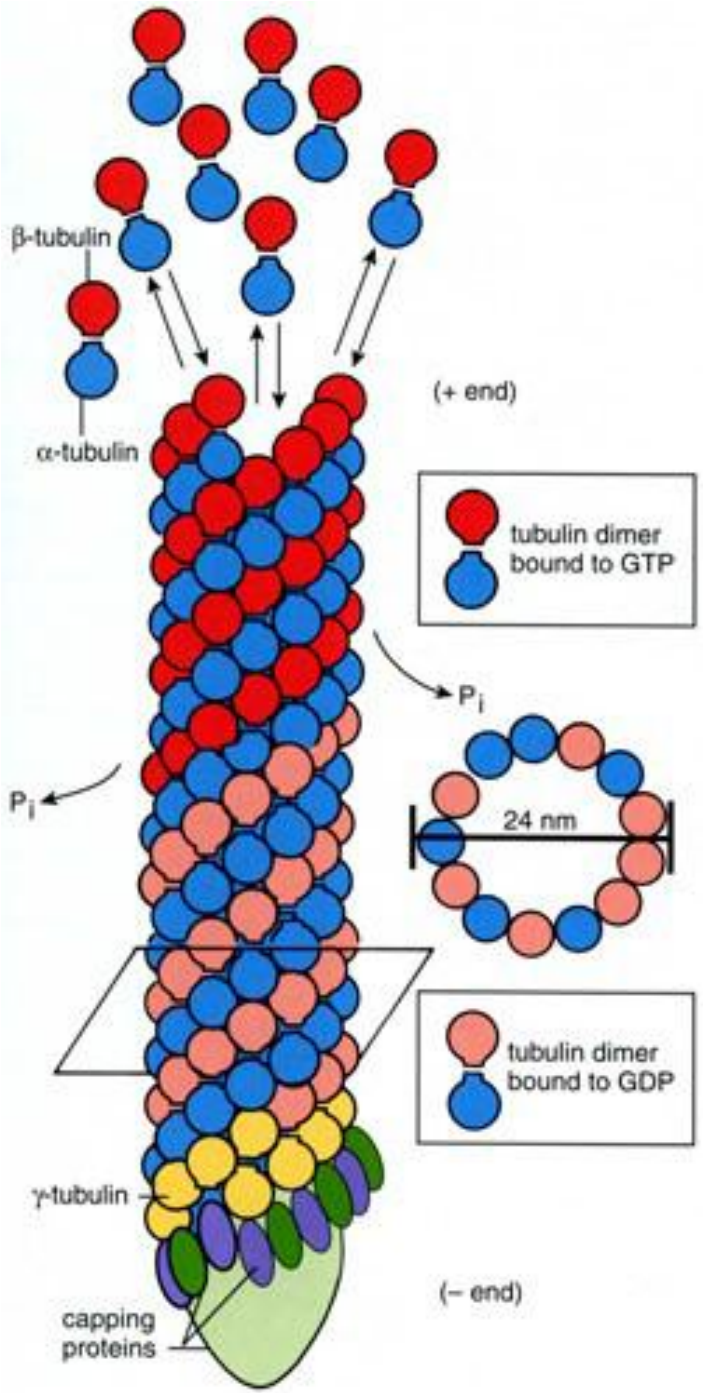
Sifat	Mikrotubulus (Polimer Tubulin)	Mikrofilamen (Filamen Aktin)	Filamen Intermediat
Struktur	Tabung berongga, dinding terdiri dari 13 kolom molekul tubilin	2 untai aktin yg teranyam Masing2 adl polimer subunit aktin	Protein fibrosa (berserat) → kumparan → tebal
Diameter	25 nm, lumen 15 nm	7 nm	8 – 12 nm
Subunit Protein	Tubulin, dimer yang terdiri dari α-tubulin dan β-tubulin	Aktin	Salah satu protein keratin
Fungsi Utama	• Mempertahankan bentuk sel (penopang penahan-kompresi) • Motilitas sel (seperti pd silia/ flagel) • Pergerakan kromosom di pembelahan sel • Pergerakan organel	• Mempertahankan bentuk sel (unsur penahan tegangan) • Perubahan bentuk sel • Kontraksi otot • Aliran sitoplasmik • Motilitas sel sel (pseudopodia) • Pembelahan sel	• Mempertahankan bentuk sel (unsur penahan tegangan) • Tambatan nukleus dan organel tertentu • Pembentukan lamina nukleus
Mikrograf sel **Fibroblas** (*sel yang menyintesis matriks ekstraseluler, kolagen, dan kerangka struktural*) yang di beri perlakuan fluoresen			

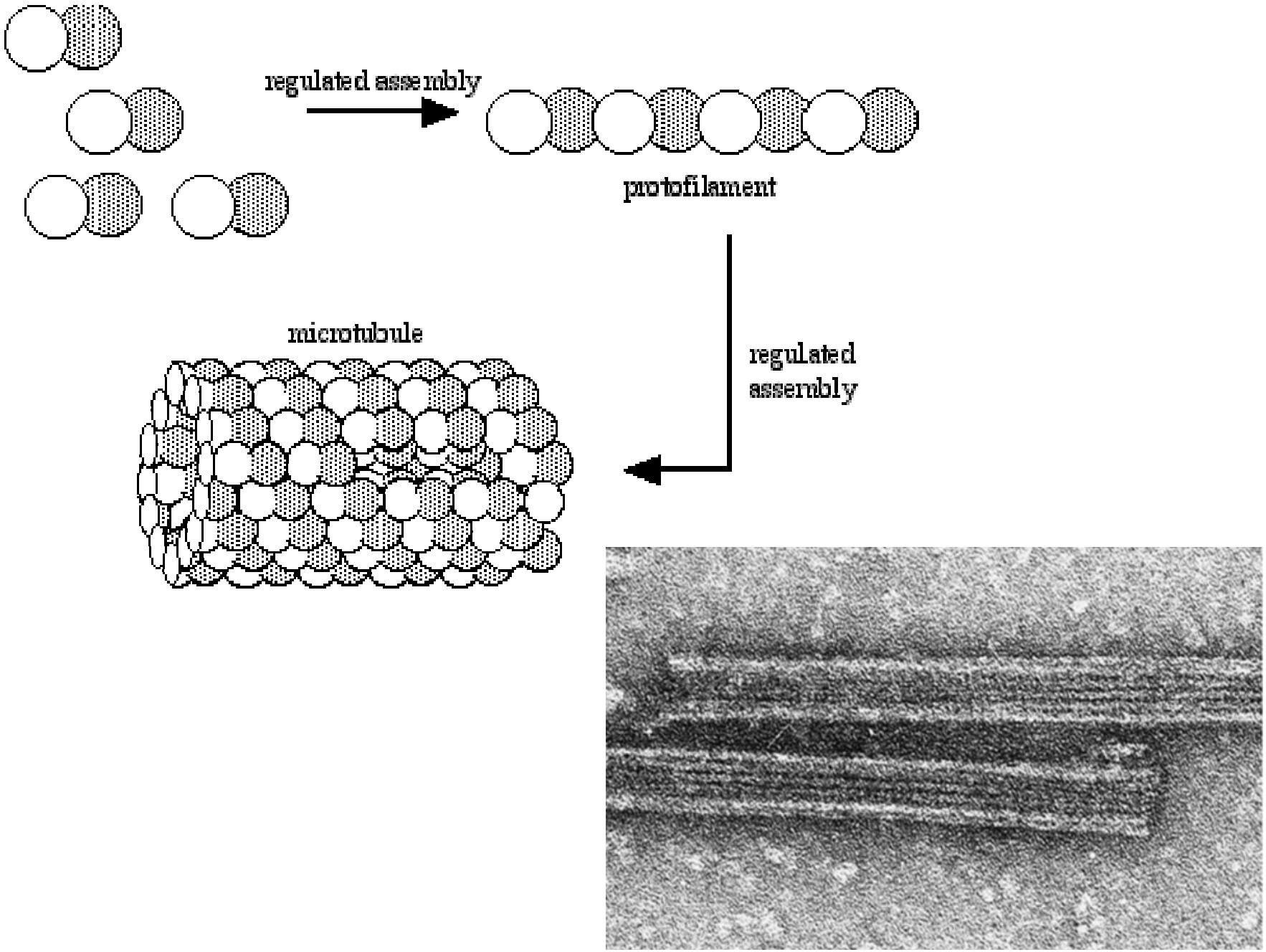
MIKROTUBULUS

Ukuran : .....??

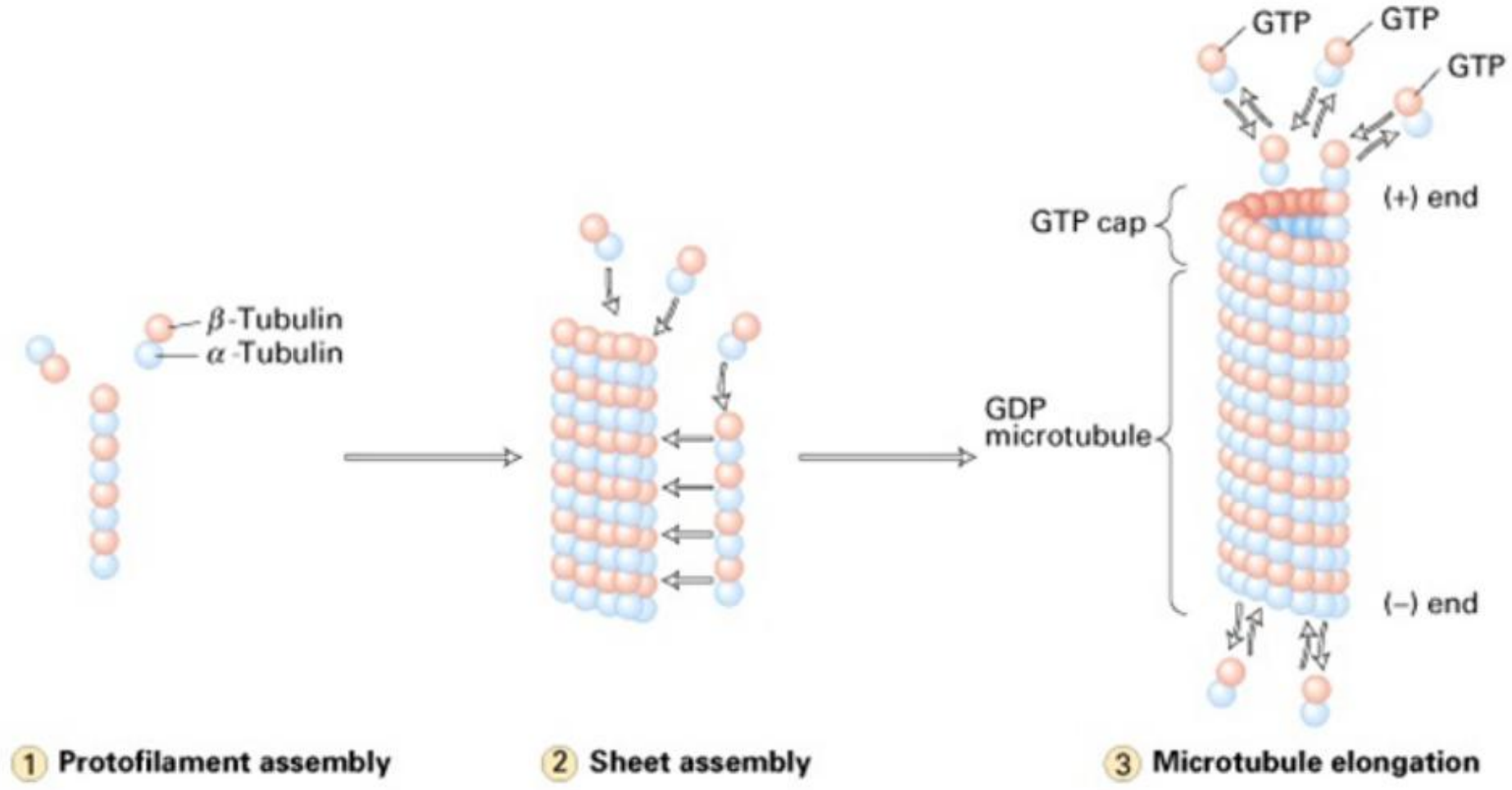
Struktur :

- Protein tubulin globular
- Subunit Heterodimer α dan β tubulin (**Protomer/ protofilamen**) yang terpolimerisasi (*Polymerize*) menjadi into Mikrotubul (**13 Protomer/ protofilamen**)
- Memiliki ujung + (*+ end*) dan ujung - (*- end*)
- GTP dependent
- *+ end* (bagian tepi) terpolimerisasi lebih cepat dari *-end* (bagian tengah)
- *Dynamic instability*

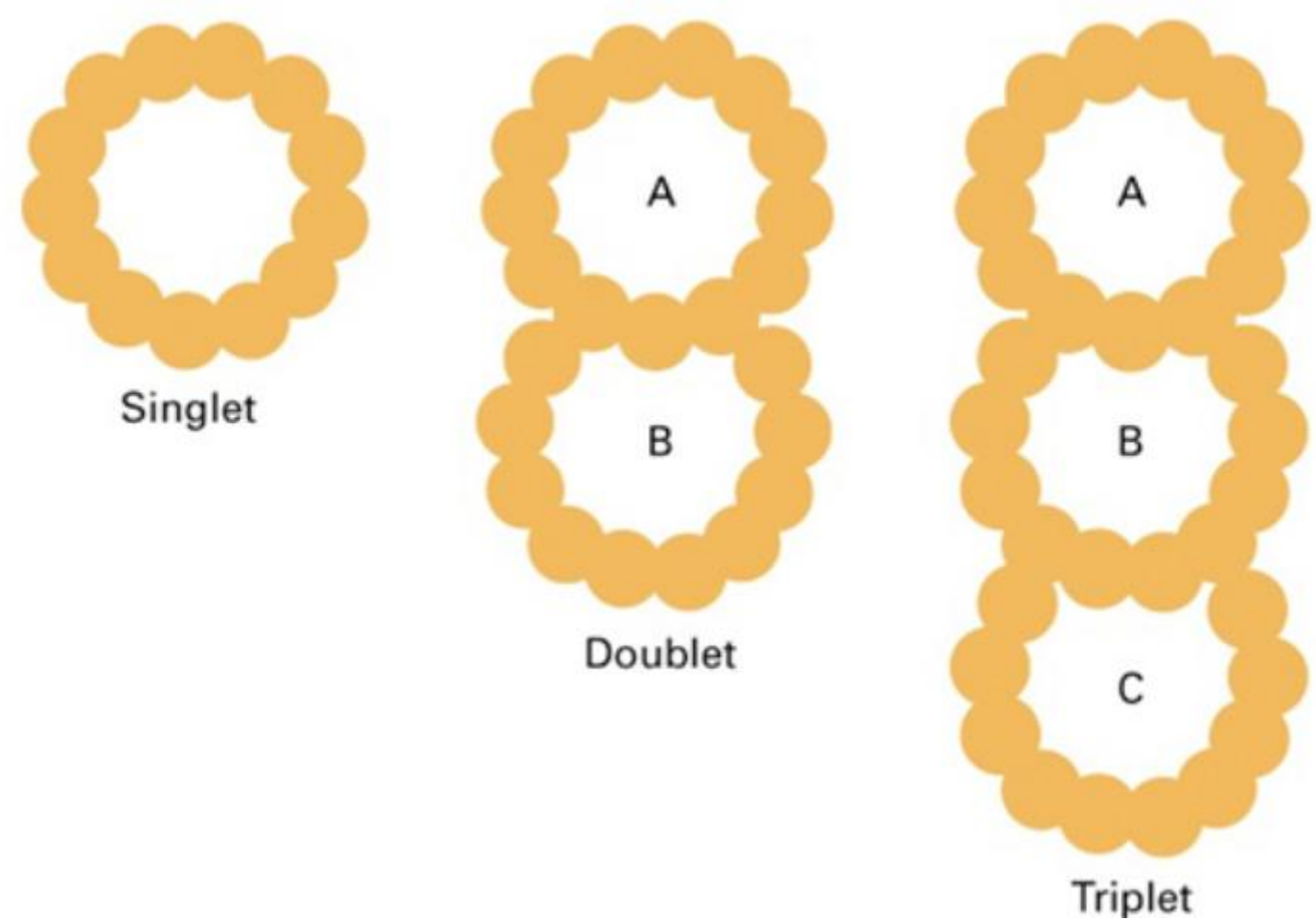



regulated assembly
protofilament
microtubule
regulated
assembly

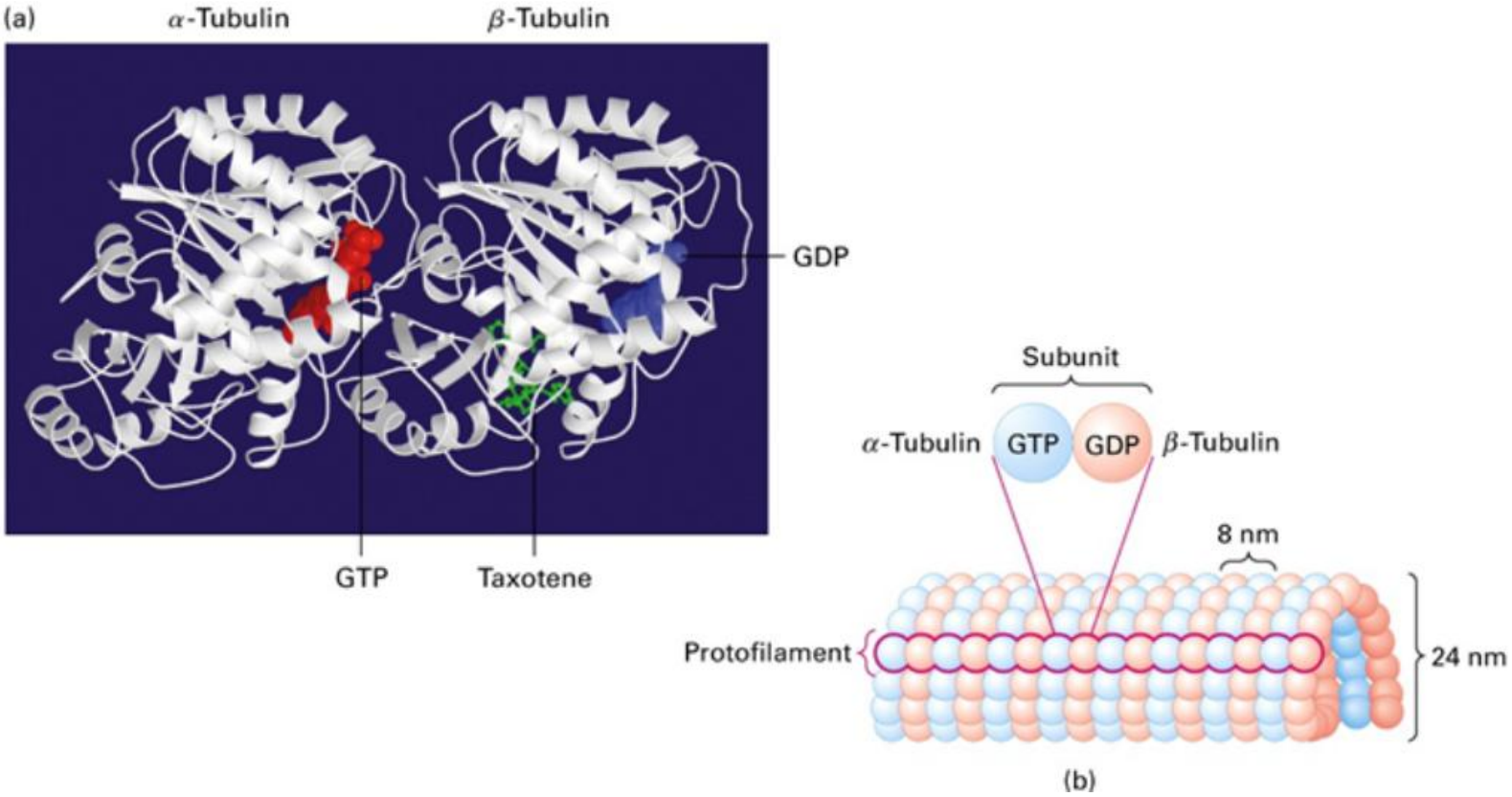
TAHAP PERAKITAN MIKROTUBULUS

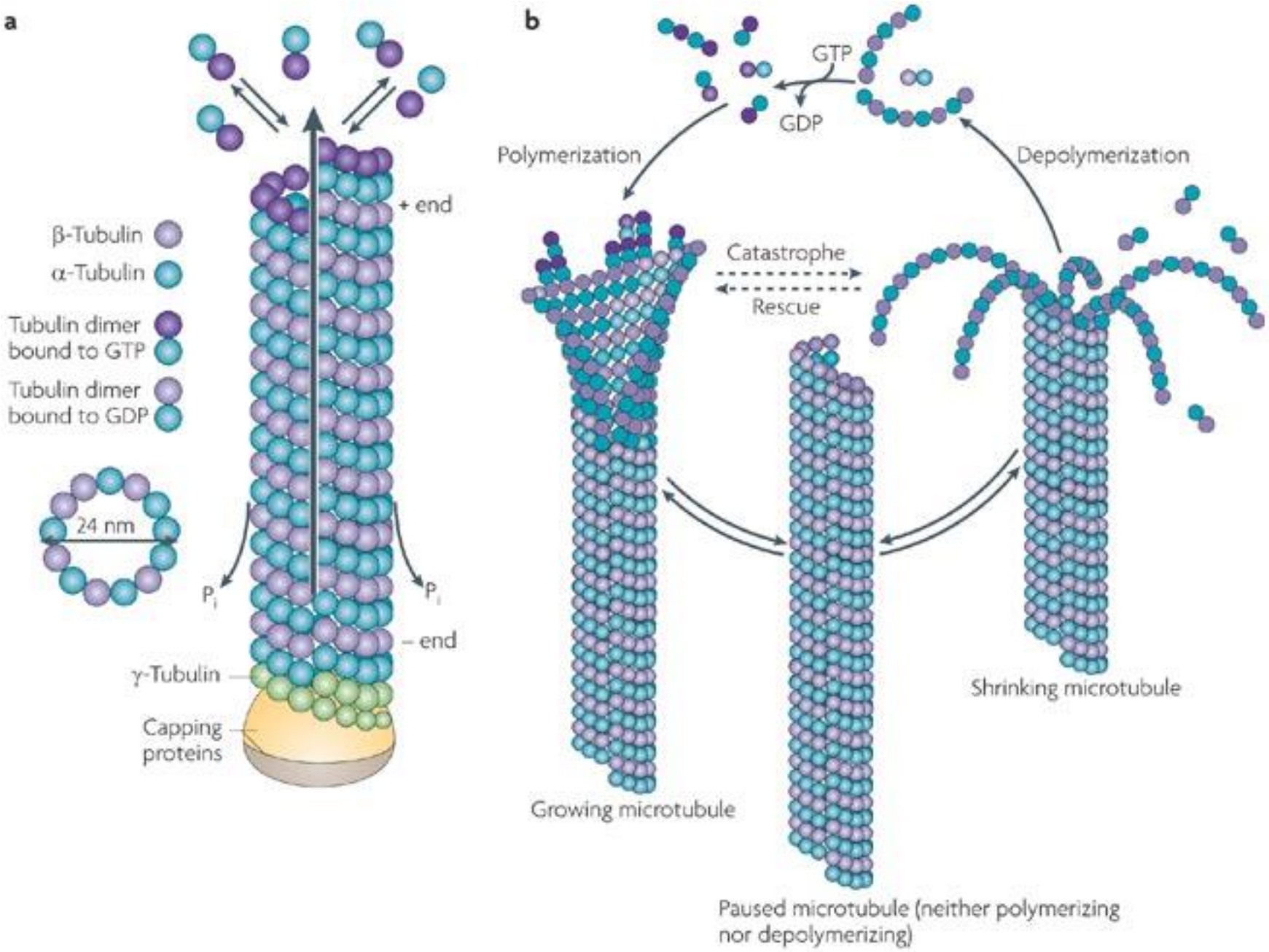


STRUKTUR PROTOFILAMEN PADA SINGLE, DOUBLE DAN TRIPLE MIKROTUBULUS

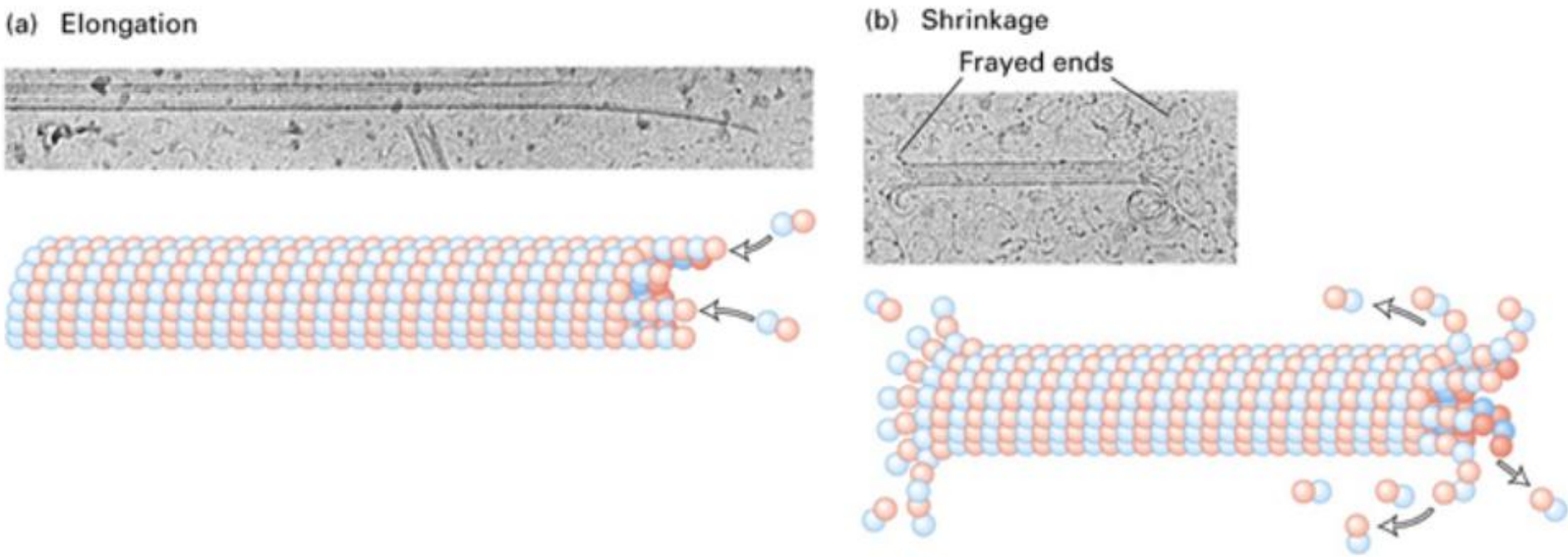


- Mikrotubulus merupakan komponen sitoskeleton yang utama
- Ditemukan di semua sel eukariotik
- Satu mikrotubulus mengandung 10 sampai 15 protofilamen (sel mamalia 13) yang membentuk silinder
- Struktur mikrotubulus dapat secara cepat **terbentuk/ tumbuh** (melalui **polimerisasi**) atau **terurai** (melalui **depolimerisasi**) tergantung berapa banyak molekul tubulin yang ada




a
β-Tubulin
α-Tubulin
Tubulin dimer bound to GTP
Tubulin dimer bound to GDP
24 nm
+ end
– end
P_i
P_i
γ-Tubulin
Capping proteins
b
GTP
GDP
Polymerization
Depolymerization
Catastrophe
Rescue
Growing microtubule
Shrinking microtubule
Paused microtubule (neither polymerizing nor depolymerizing)

Ujung Pertumbuhan dan Penguraian Terlihat Berbeda



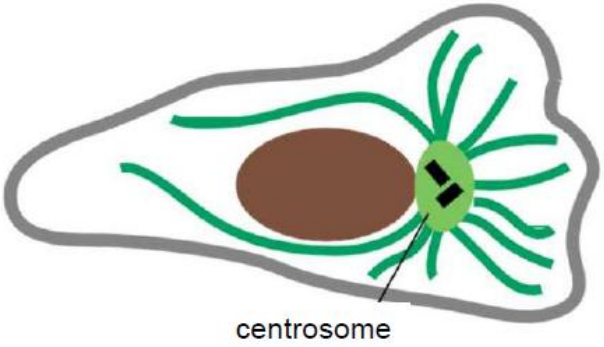
Dalam sel, ujung – (- *end*) mikrotubulus tertambat pada struktur yang disebut ***Microtubule Organizing Centers (MTOCs).*** MTOC utama sel disebut **Sentrosom centrosome**, dan biasanya berdekatan dengan nukleus

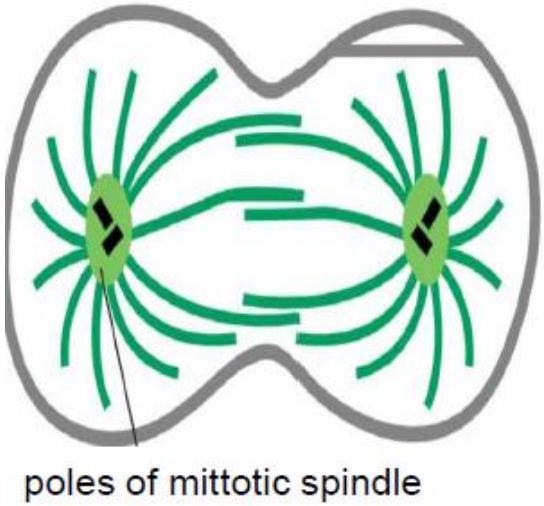
Pusat Organisasi Mikrotubulus

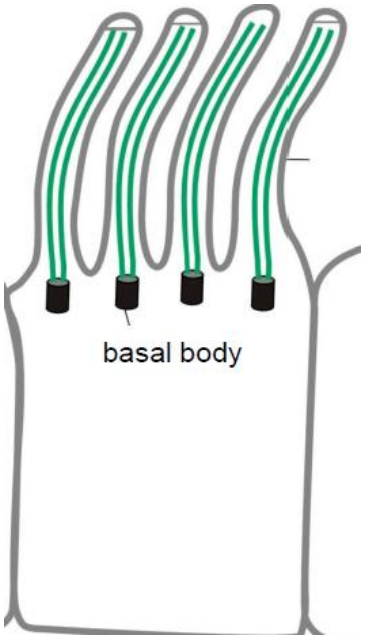
1. **Sentrosom (Centrosome)**
2. **Benang-benang spindel pembelahan (mitotic spindle)**
3. **Basal Body**

Function:

- maintain the **cell shape, anchor organelles**
- **movement - flagellar, ciliary, intracellular**
- **mitosis – mitotic spindle**





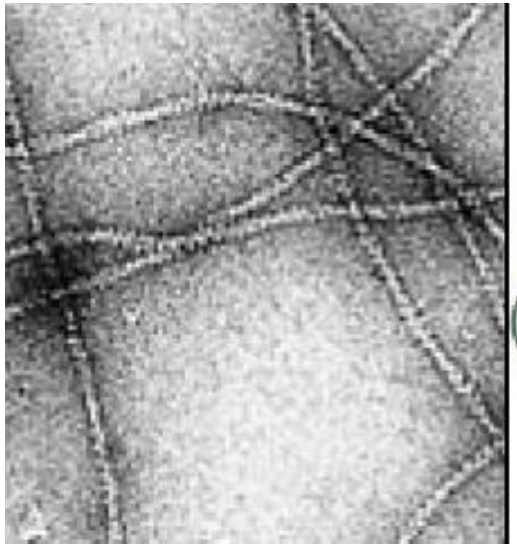


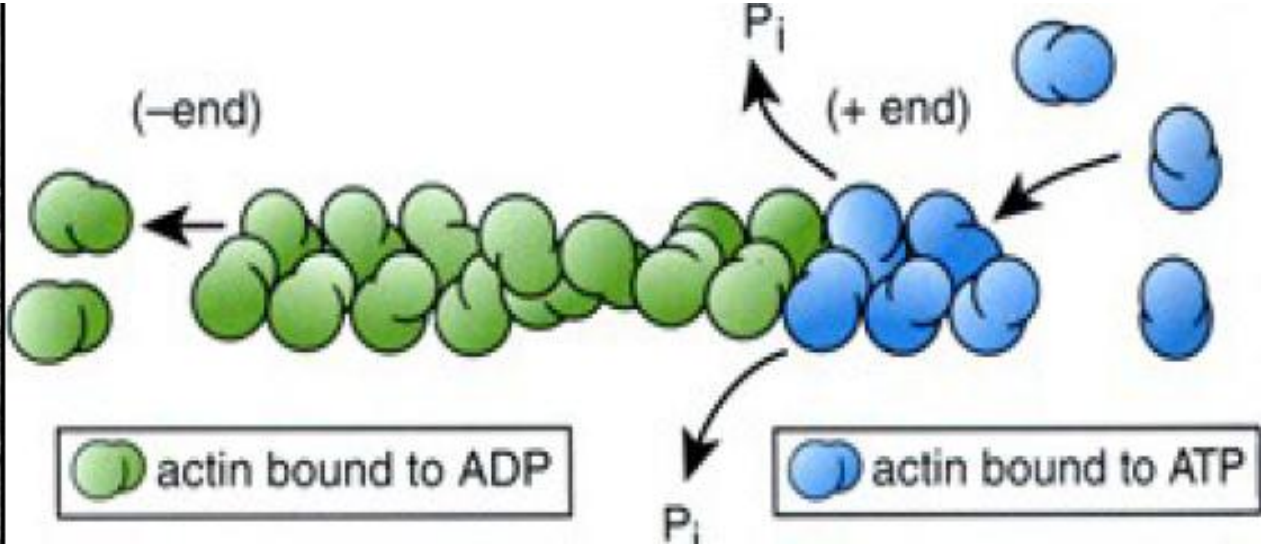
AKTIN FILAMEN (MIKROFILAMEN)

Ukuran : .....??

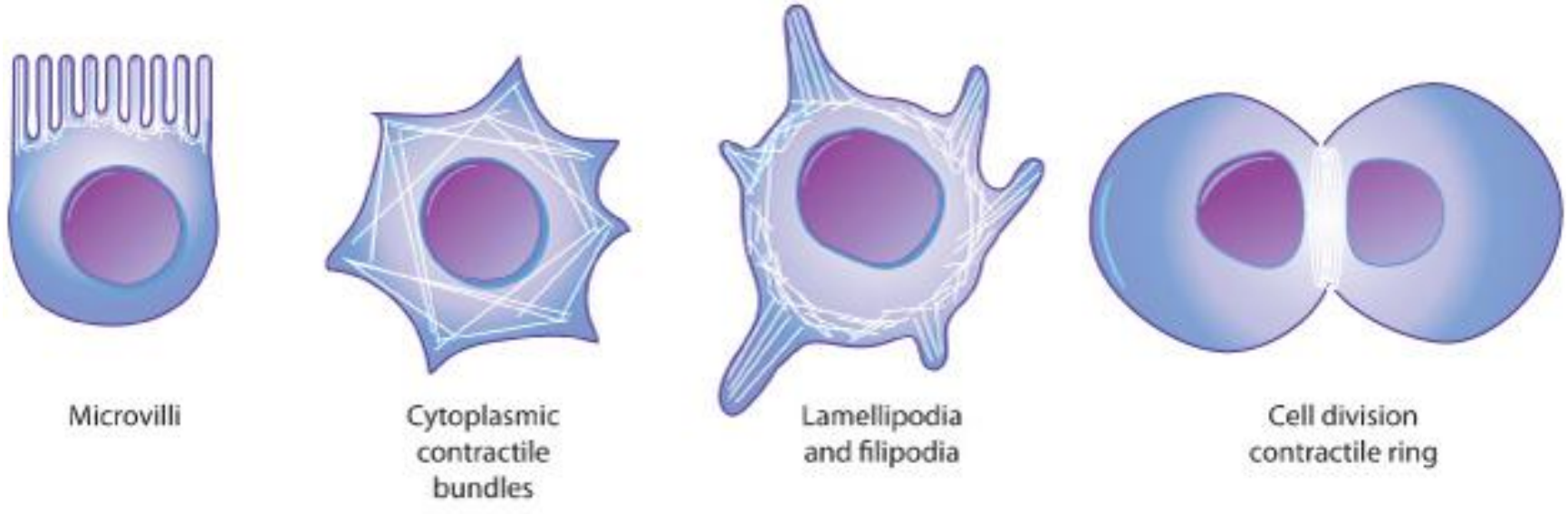
Struktur:

- Filamen terbentuk dari **protein aktin globular** (Monomer)
- Terpolimerisasi membentuk **Dimer** → **Trimer**
- ATP dependent
- Ujung + dan Ujung -, lebih banyak pertumbuhan dengan tenaga ATP yg terjadi di ujung +
- *Dynamic Instability*





- Protein aktin jumlahnya banyak di semua sel eukariotik
- Petama kali ditemui di otot rangka, dimana aktin filamen meluncur sepanjang filamen protein lain yg disebut **MIOSIN**, membuat sel berkontraksi (pada sel selain sel otot, filamen aktin kurang dan miosin hampir tidak ada)
- **Filamen aktin dibuat dari protein aktin yang identik** menjadi rantai spinal yg panjang
- Pada banyak tipe sel, jaringan filamin aktin ditemukan di bawah **Korteks Sel**, yang berasosiasi dengan protein asosiasi membran → shg mensuport dan menguatkan membran plasma
- Filamen aktin juga terlibar dalam **sitokinesis** (pemisahan sitoplasma) dan pergerakan sel



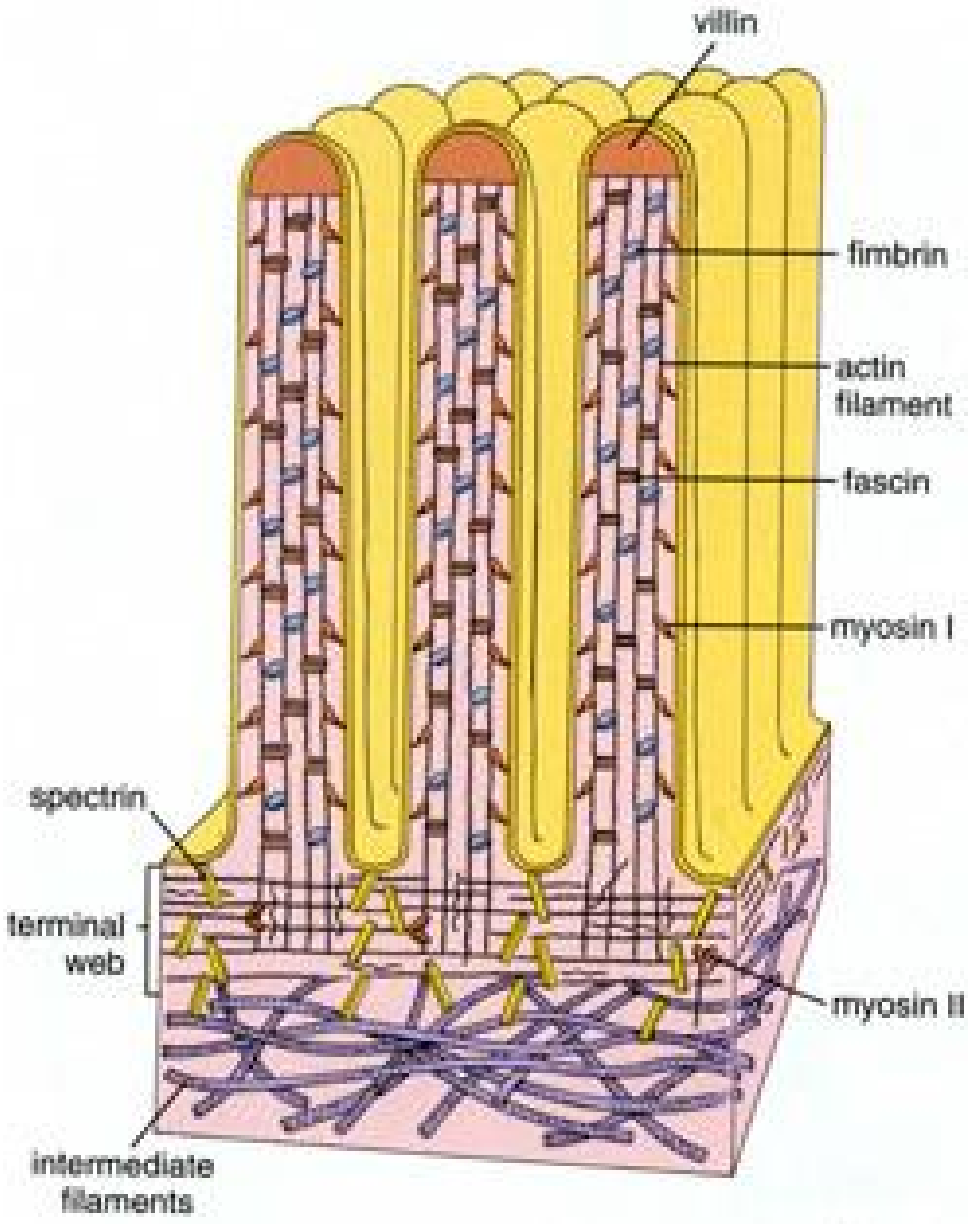
Filamen Aktin mendukung berbagai struktur dalam sel

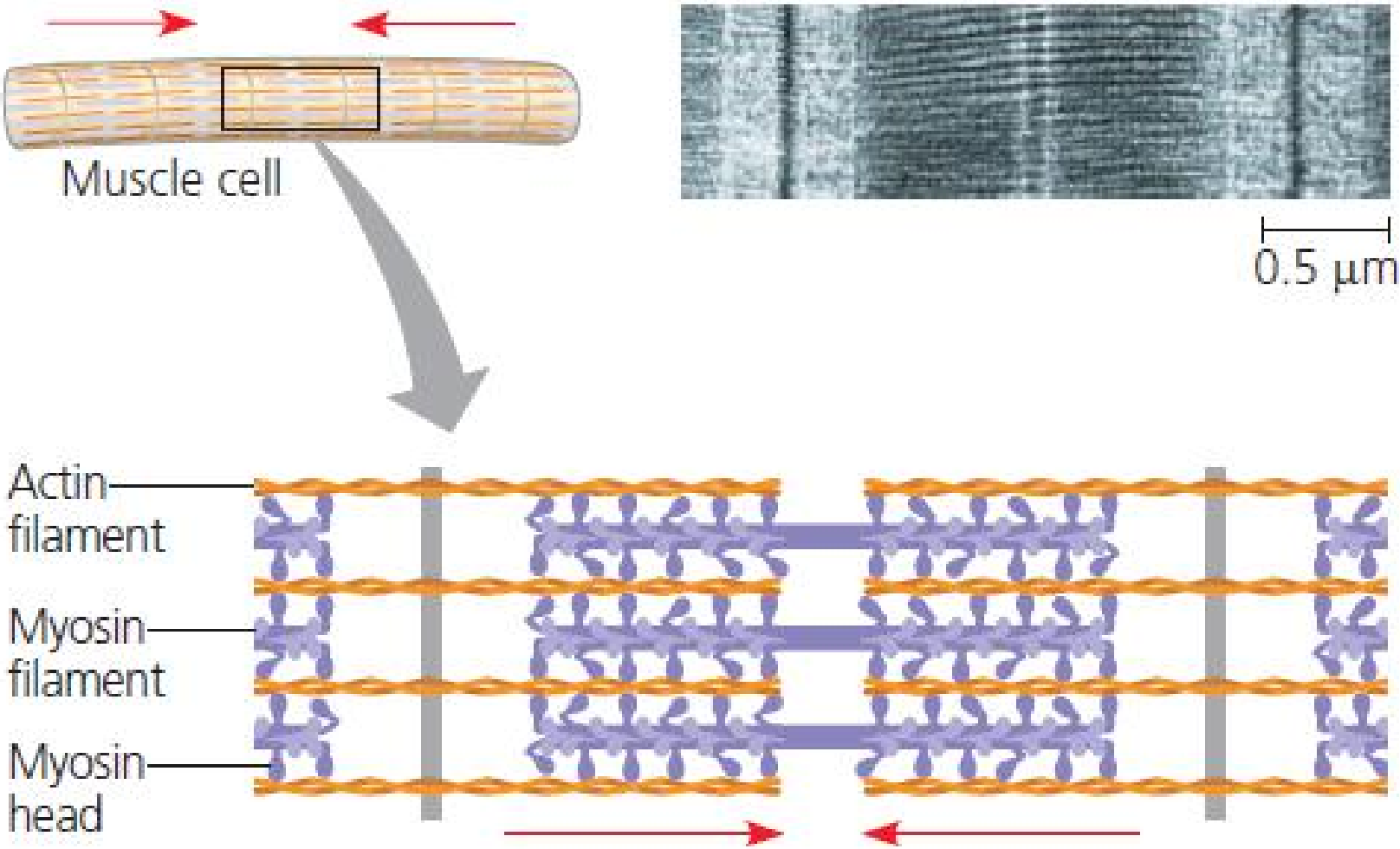
Molecular motors:

- **Myosin I**
- **Myosin II**

Function:

- **Structural - projection of the cell (villi of epithelial cell), polymeration of actin in acrosome helps sperm cells to perforate egg during fertilization**
- **Movement - amoeboid - muscle contraction**
- **Mitosis - contractile ring**




Muscle cell
0.5 µm
Actin filament
Myosin filament
Myosin head

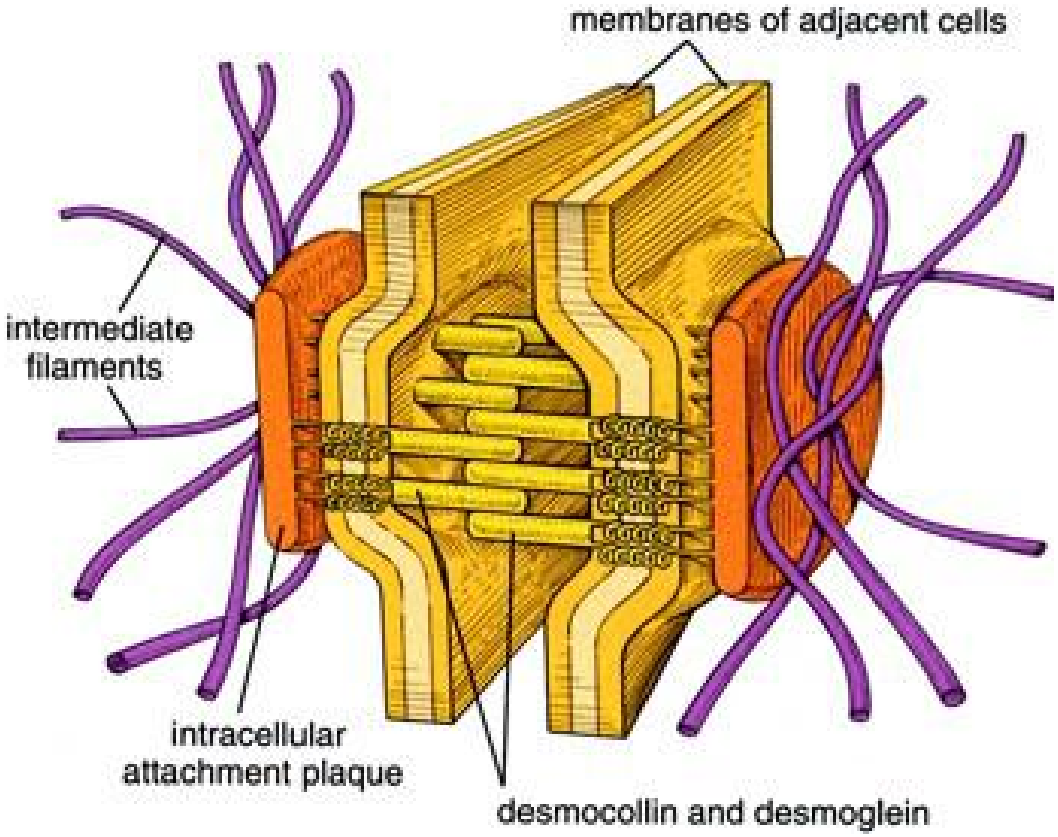
FILAMEN INTERMEDIAT

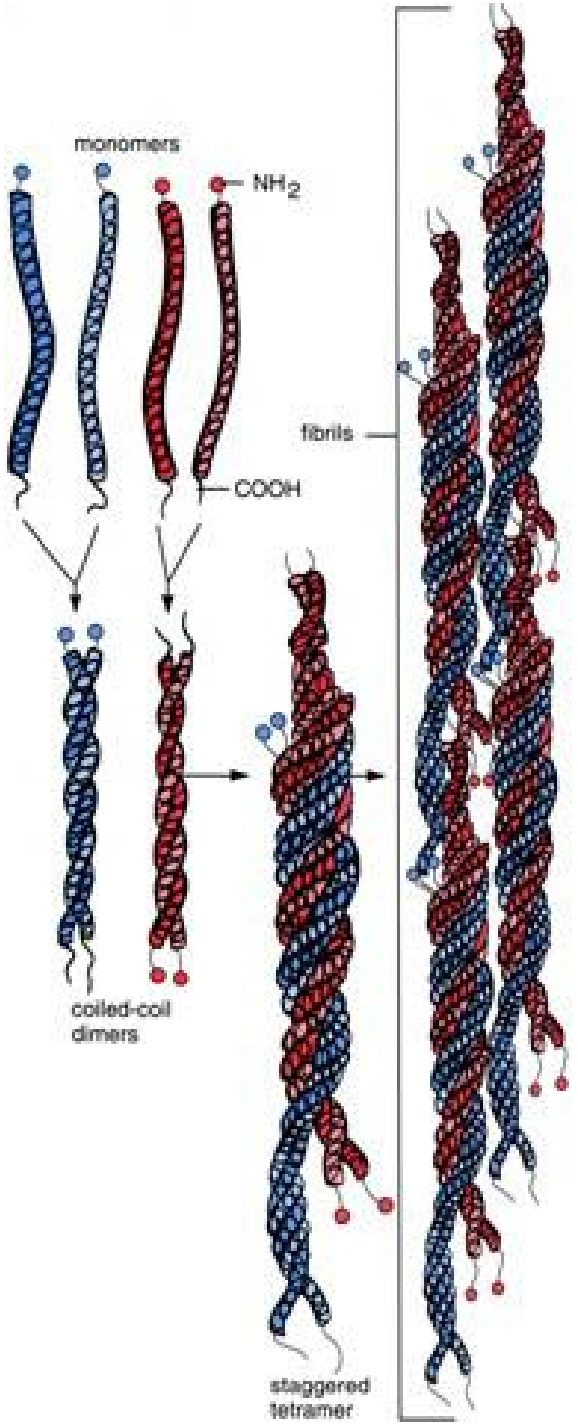
Ukuran: Diameter.....???

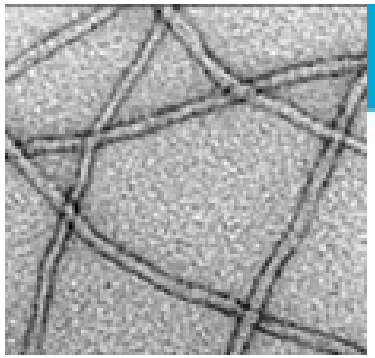
- Panjang Bervariasi

Struktur:

- Protein Alfa Heliks Berserat yang seperti Tali/ Kabel
- Terpilin, Dimer - Tetramer - Filament (8 Tetramers)
- Least Dynamic of cytoskeletal filaments



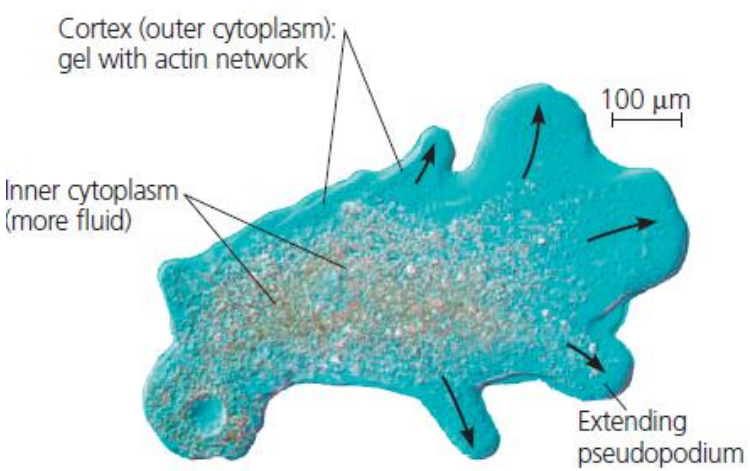




Fuction:

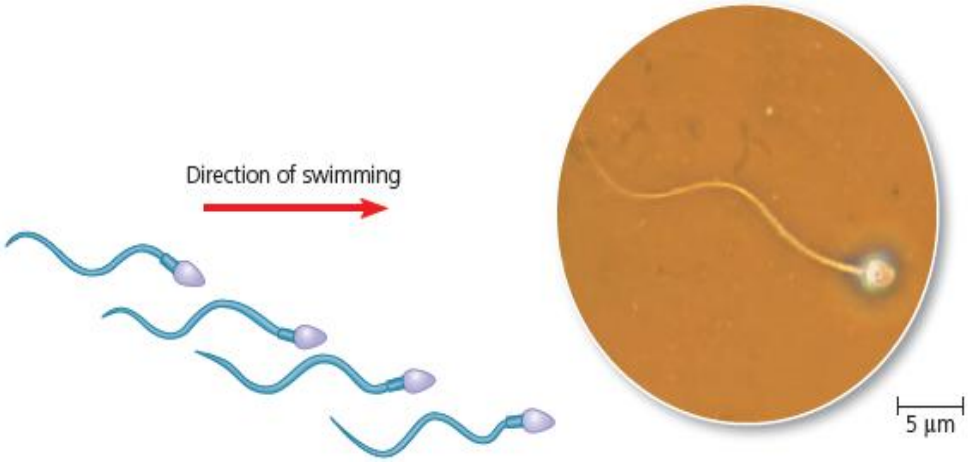
- Provide cell shape and structural reinforcement (Desmosomes)
- Anchor organelles
- Keep nucleus in place

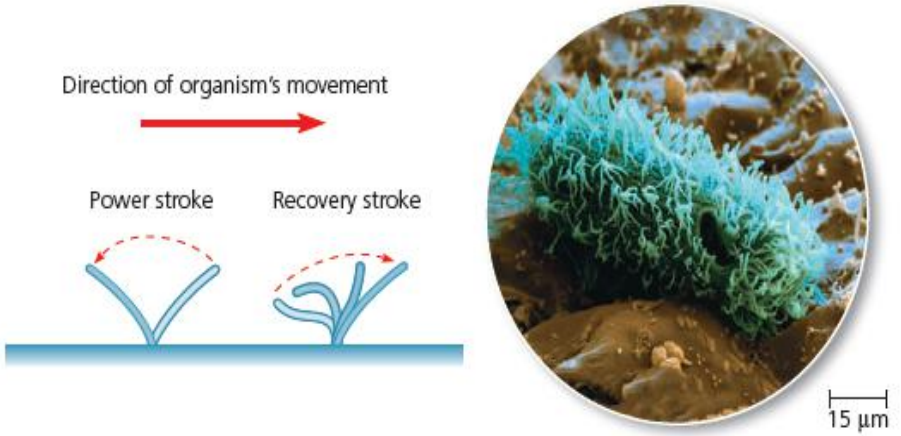
Analisislah Sitoskeleton Mana yang Berperan Dalam Aktivitas berikut



) **Amoeboid movement.** Interaction of actin filaments with myosin causes contraction of the cell, pulling the cell's trailing end (at left) forward (to the right) (LM).

Cytoplasmic streaming in plant cells. A layer of cytoplasm cycles around the cell, moving over a carpet of parallel actin filaments. Myosin motors attached to organelles in the fluid cytosol may drive the streaming by interacting with the actin (LM).





SITOSKELETON PROKARIOTIK

Sitoskeleton sel prokariotik termasuk:

- **Tubulin Homolog** terdiri dari: **FtsZ, BtuA, BtuB** dan beberapa protein asosiasi yg berperan penting dalam pembelahan sel
- **Actin-like Homolog** Seperti **MreB dan Mb1**, yang terlibat dalam mengontrol panjang dan lebar sel
- ***Intermediat Filamen Homolog***, termasuk **Crescentin** dan **CfpA**, yang berada bagian *concave* bakteri dan sepanjang *inner curvature* dan terasosiasi dengan membran.

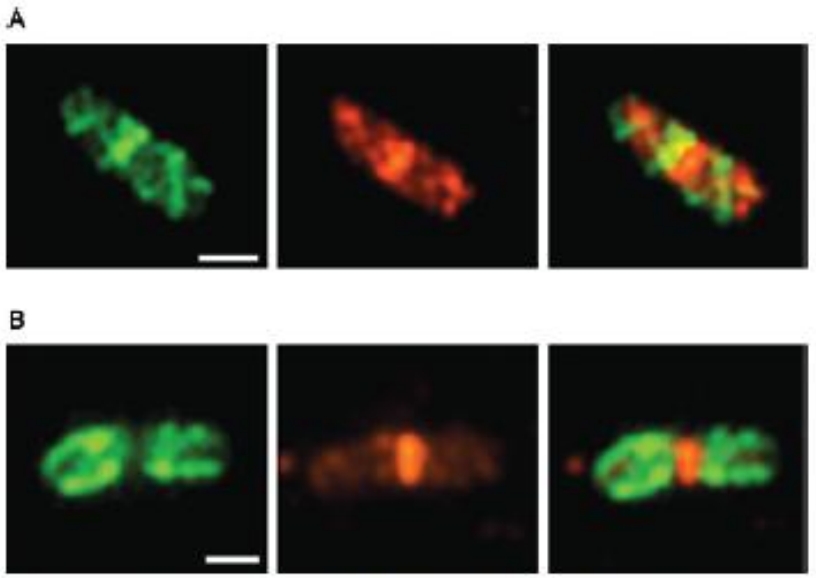
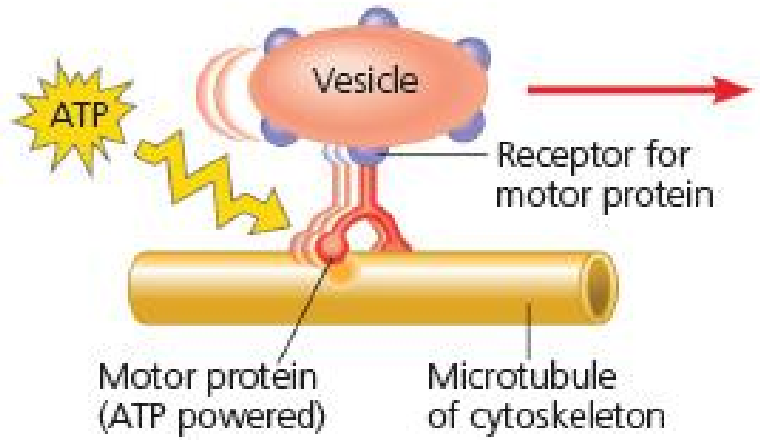


Fig. 4: immunolocalisation of FtsZ (in red) and MreB (in green) in *Escherichia coli* (A, B) showing the MreB splitting during the cell cycle in association with FstZ. Bar = 1 µm (after Vats & Rothfield 2007).

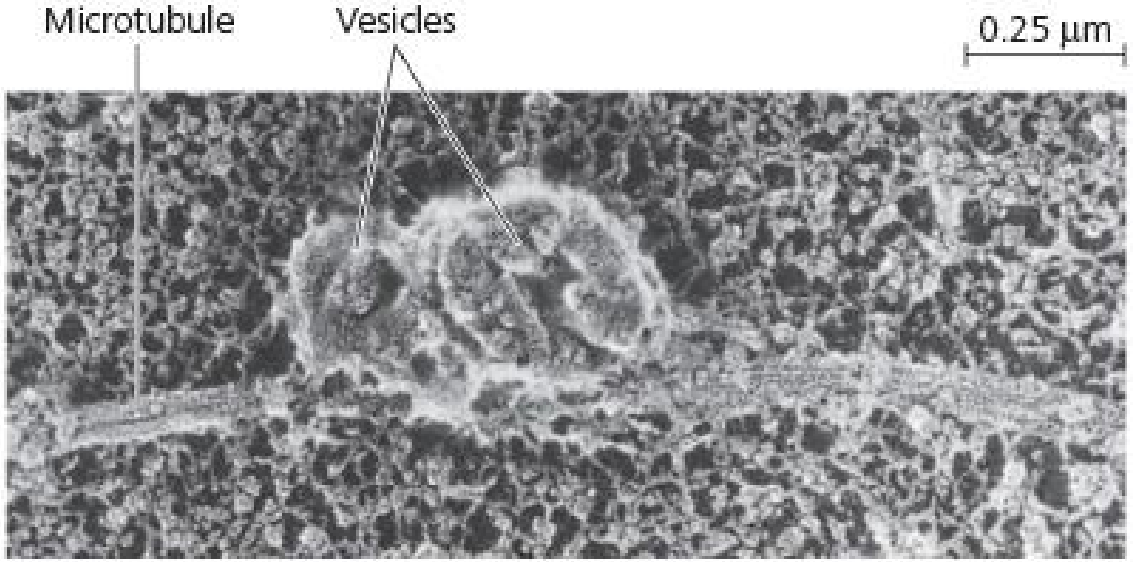
Wanderley de Souza. 2012. Prokaryotic cells: structural organisation of the cytoskeleton and organelles. *Mem Inst Oswaldo Cruz, Rio de Janeiro. 107(3): 283-293*

PRINSIP PERGERAKAN

Transformasi energi kimia menjadi mekanik



(a) Motor proteins that attach to receptors on vesicles can "walk" the vesicles along microtubules or, in some cases, along microfilaments.

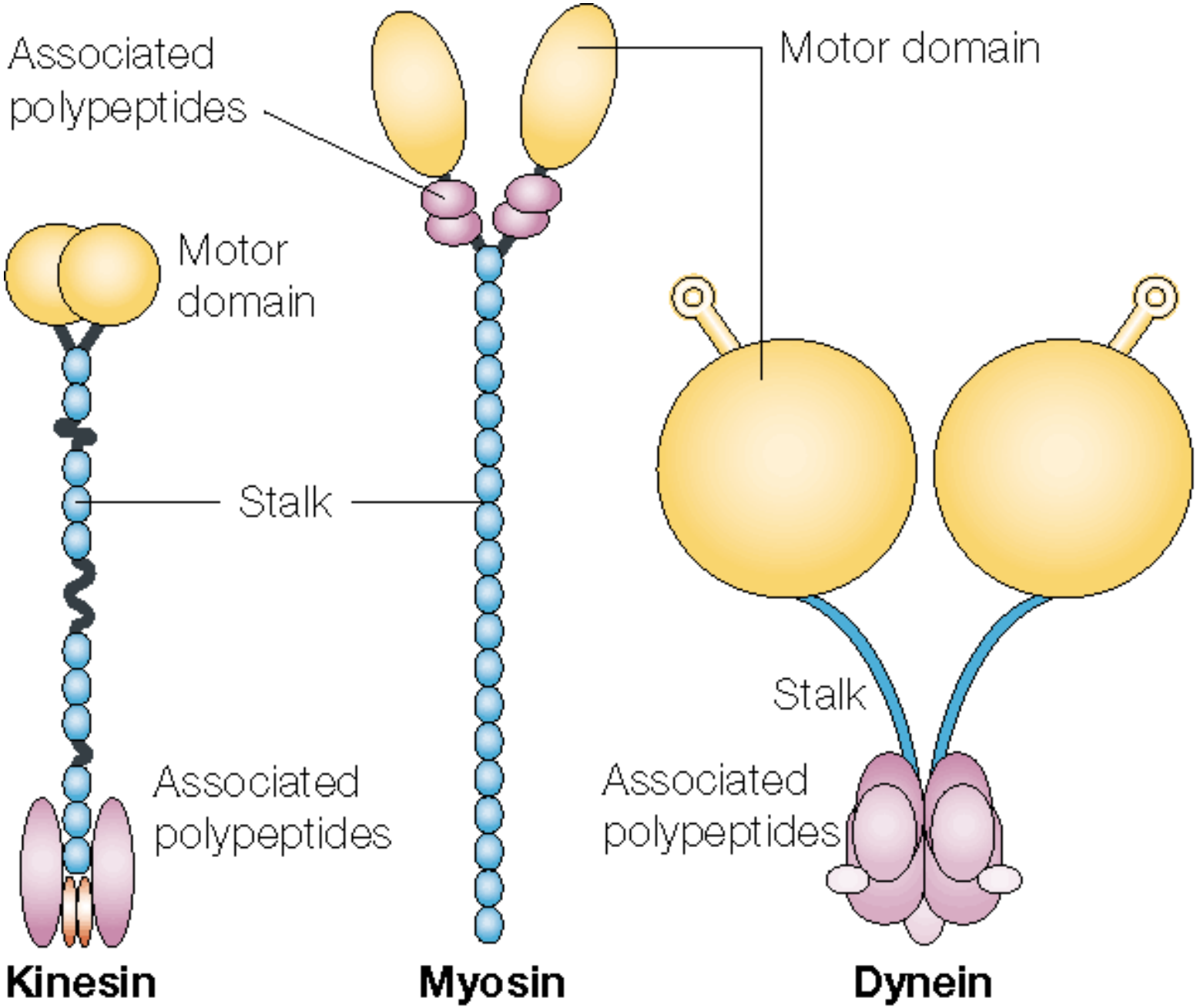


(b) In this SEM of a squid giant axon (a nerve cell extension), two vesicles containing neurotransmitters move toward the axon's tip.

Molekular Motor (Protein Motor):

Bagian Motor (Kepala) - 1 Rantai Polipeptida, Aktivitas ATPase (melepas energi krn hidrolisis ATP)

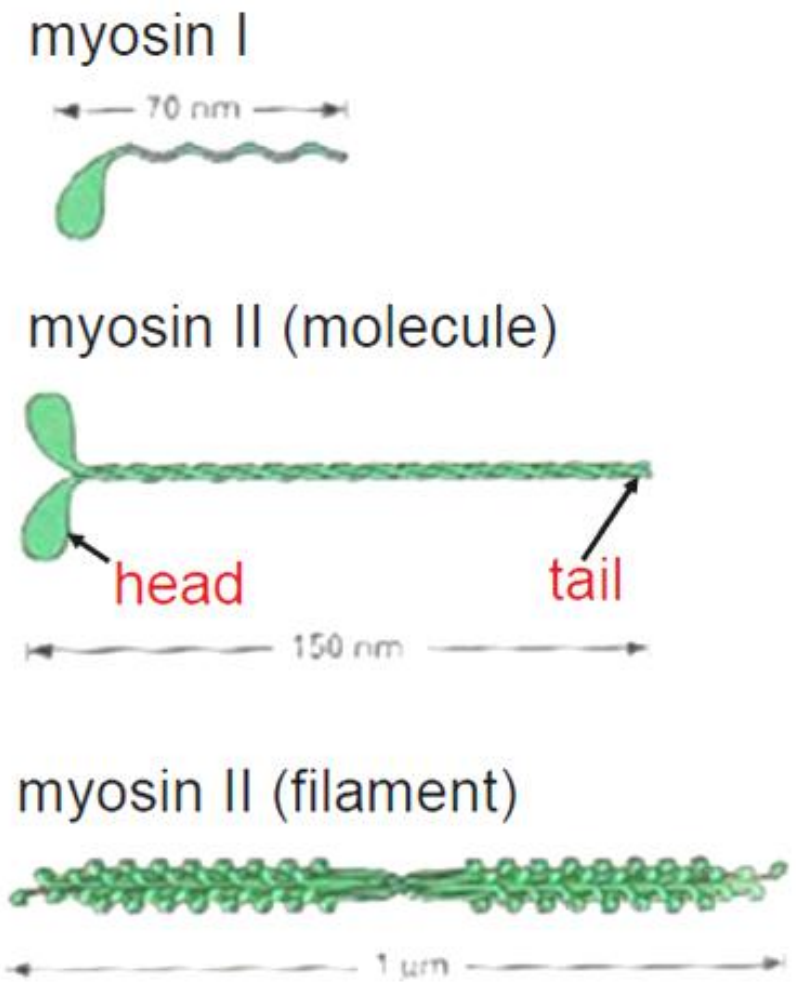
Bagian Ekor (Stalk) – Rantai Polipeptida lain, Situs Pengikat (Binding Site) untuk molekul atau Struktur sel


Associated
polypeptides
Motor domain
Motor
domain
Stalk
Stalk
Associated
polypeptides
Associated
polypeptides
Kinesin
Myosin
Dynein

MOTOR YANG DIASOSIASI DENGAN FILAMEN AKTIN

MIOSIN I: Satu daerah motor one motor domain, semua tipe sel

MIOSIN II: Dua daerah motor, filamen pada sel otot rangka

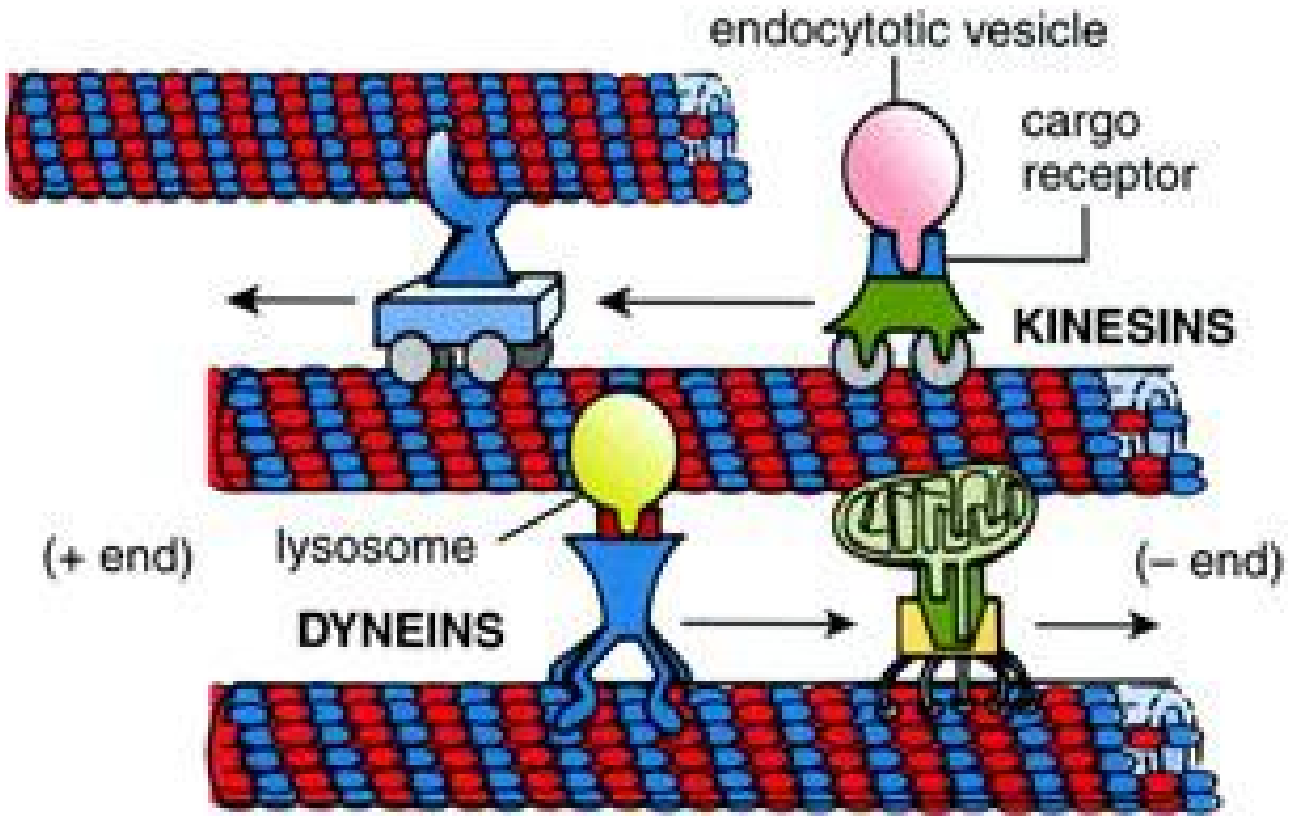


MOTOR YANG DIASOSIASI DENGAN MIKROTUBULUS

Mikrotubulus merupakan Jalur/ Track untuk Mikrotubulus lain yang berbasis protein motor yang mendistribusikan vesikel ke berbagai tujuan dalam sel

DINEIN: ke arah ujung – (*minus end directed*)

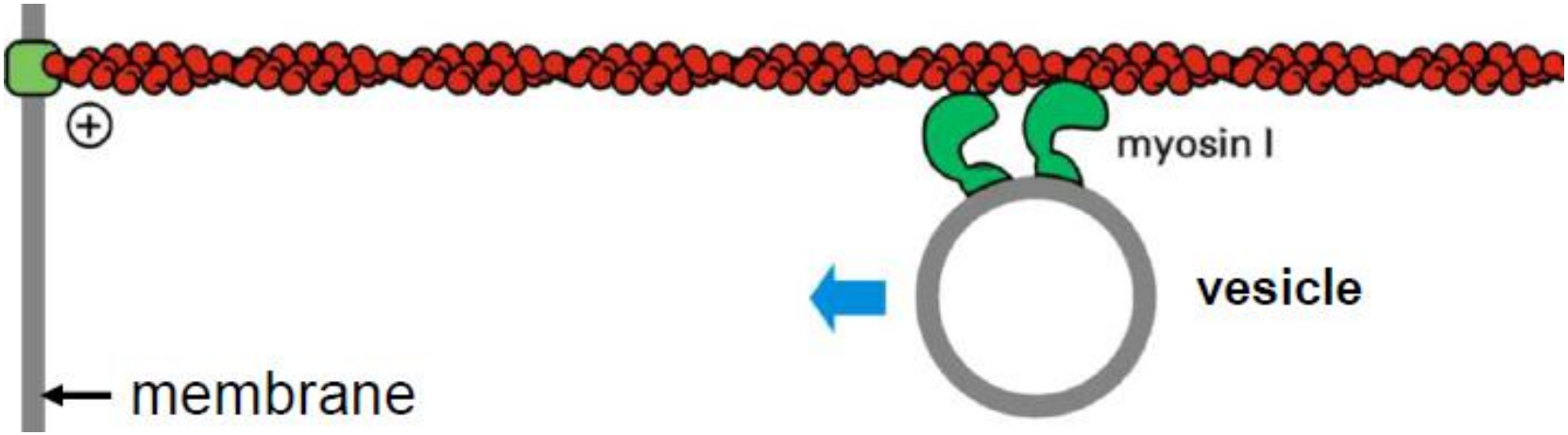
KINESIN: ke arah ujung + (*plus-end-directed*)



Tipe Pergerakan Motor

A. STRUKTUR SITOSKELETON TETAP (*Cytoskeletal Structure- Fixed*)

- Motor mengikat sitoskeleton yang strukturnya tetap/ terikat
- Hidrolisis ATP
- Motor mengubah formasi dan bergerak sepanjang struktur sitoskeleton
- Molekul Kargo bergerak bersama motor

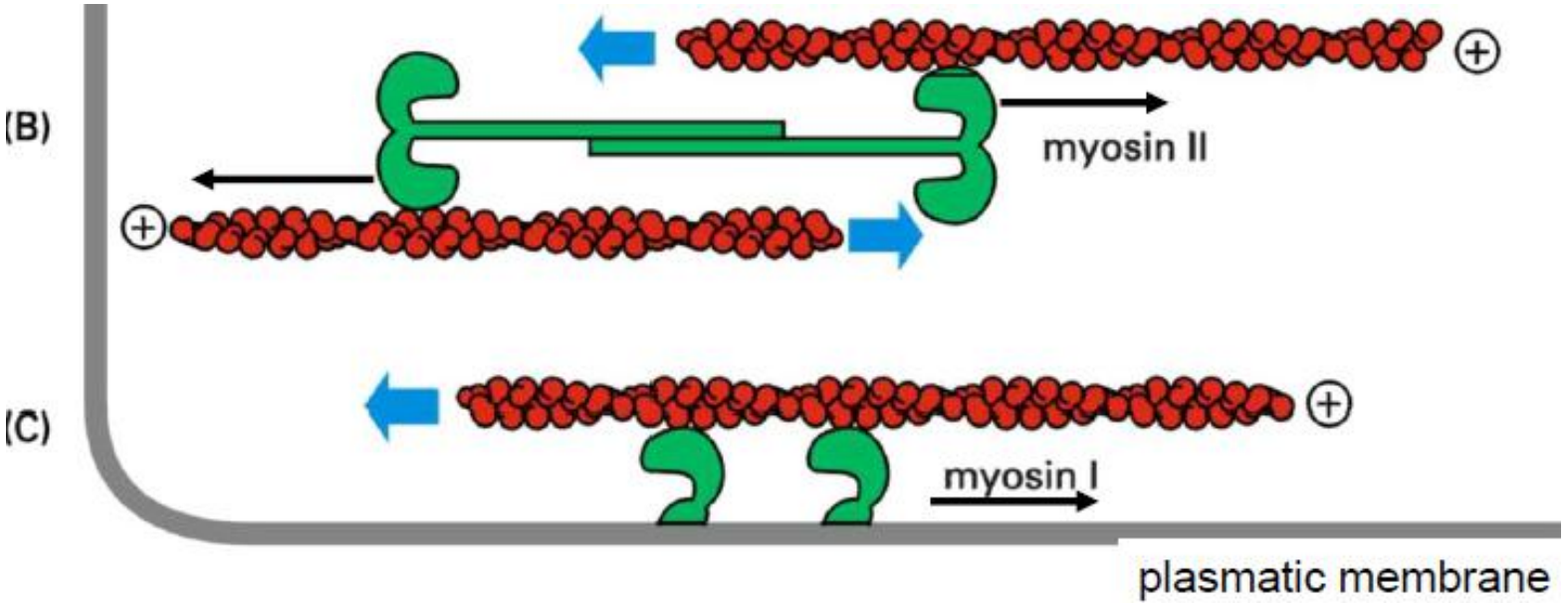


Tipe Pergerakan Motor

B. MELUNCUR (*Sliding*)

Motor tetap (*Fixed*) dengan ekor terikat pada satu struktur sitoskeleton ketika motor berinteraksi dengan sitoskeleton lain → struktur sitoskeleton meluncur

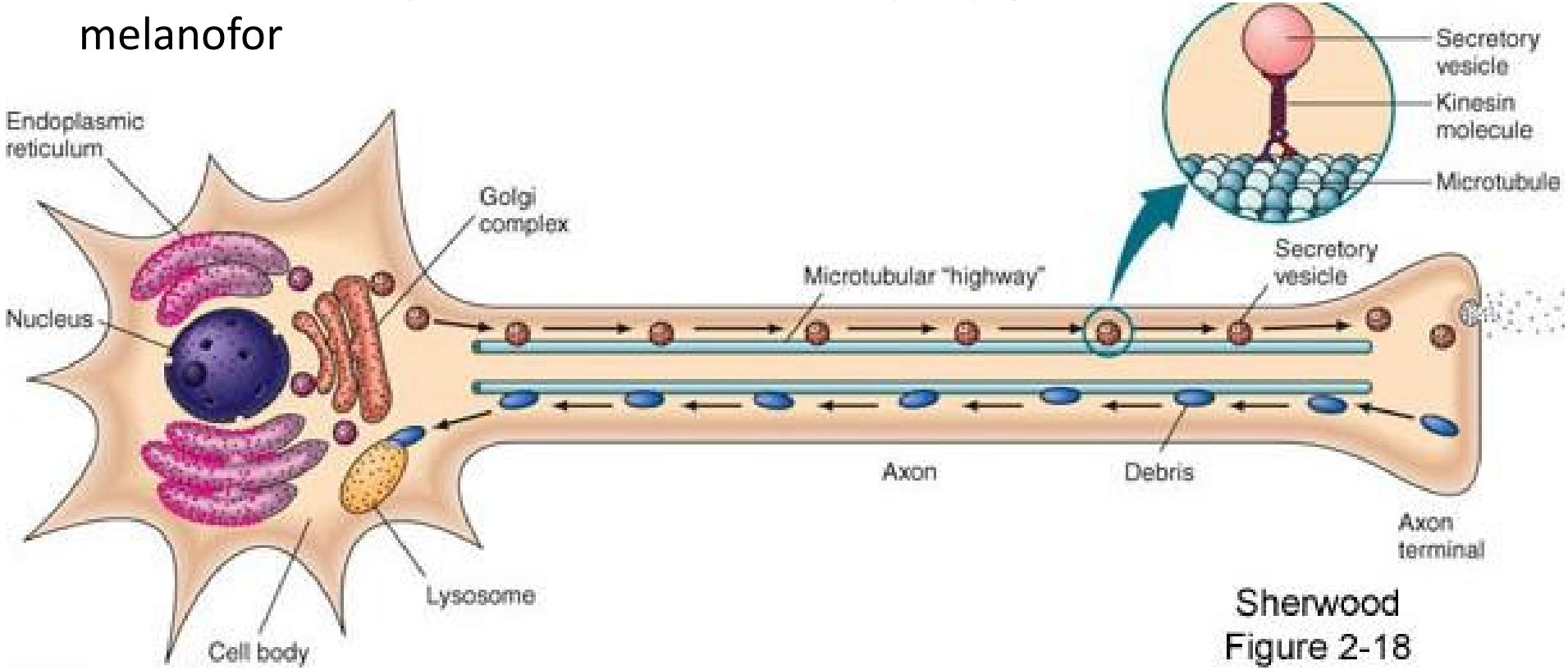
C. MOTOR TETAP (*Motor – Fixed*)



TRANSPOR INTRASELULER OLEH MOTOR

Transpor *Secretory Vesicle* oleh motor molekuler (**DINEIN, KINESIN**) sepanjang JALAN MIKROTUBULUS **(*Microtubule Highway*)**

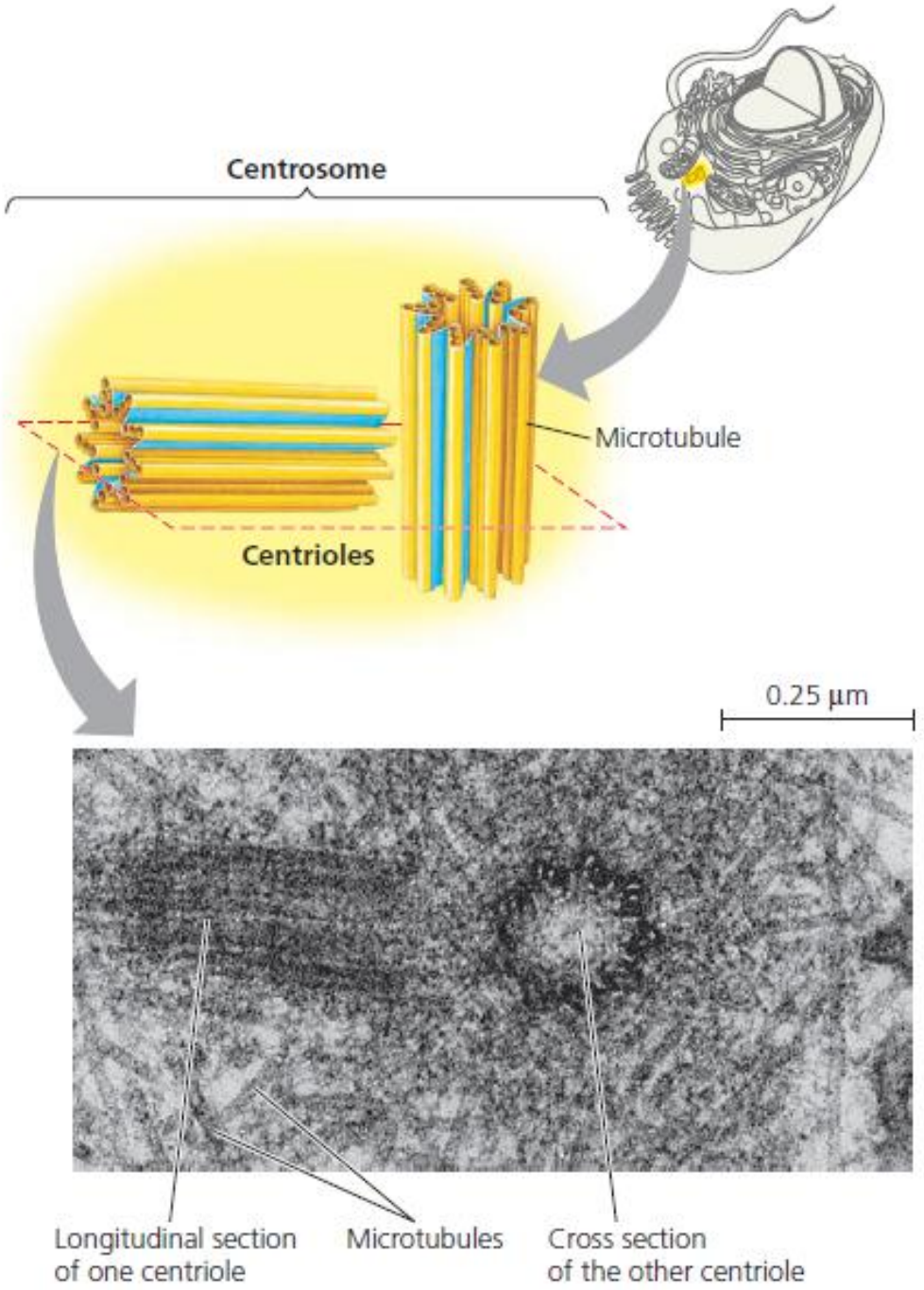
Ex: Jalur *secretory* di akson sel saraf, transpor pigmen melanofor



Sherwood
Figure 2-18

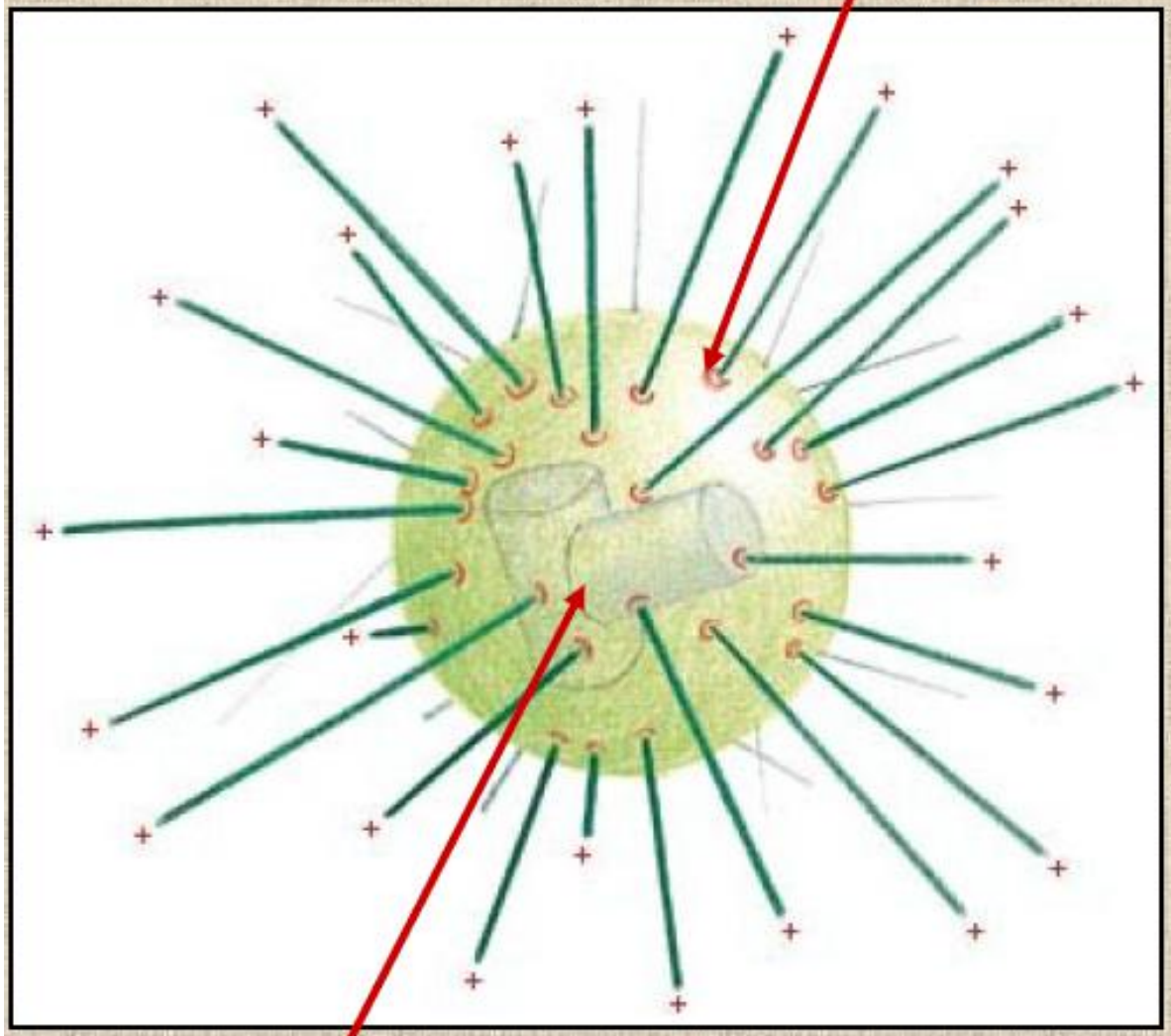
SENTROSOM

- Berperan dalam **pembelahan sel**
- Terbentuk dari **9 Triplet Mikrotubulus** yang disusun dalam lingkaran dan terkait secara lateral (menyamping)
- Dua **sentriol** (90 derajat) merupakan komponen sentrosom
- Ditemukan **dekat nukleus sel hewan** pada tahap **Interfase**
- Sentriol berduplikasi selama **Fase S** dan bergerak ke arah kutub berlawanan dari sel dan membentuk **pusat organisasi benang spindel mitosis**

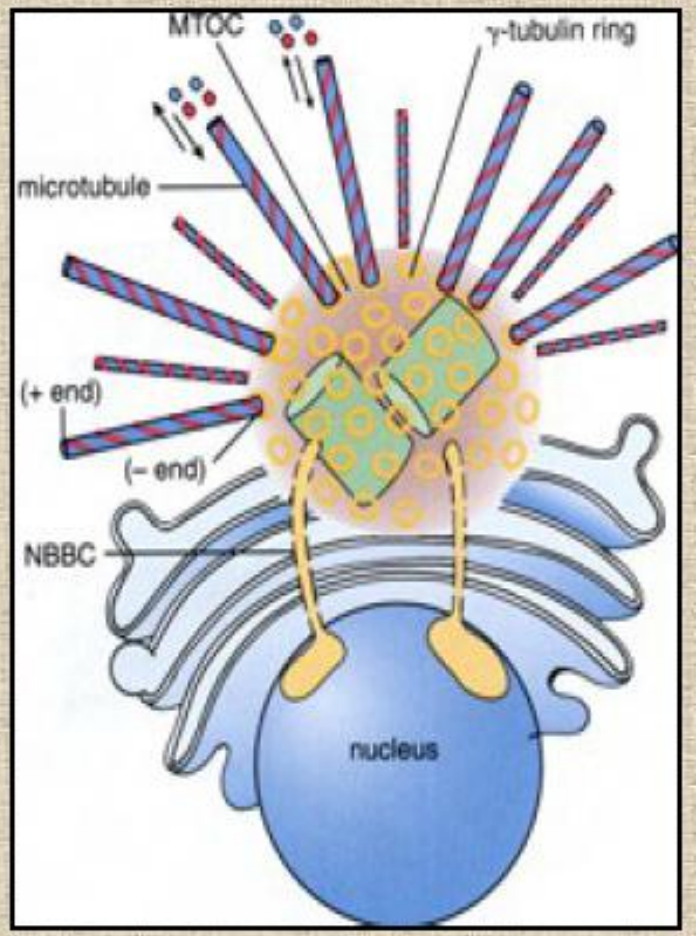


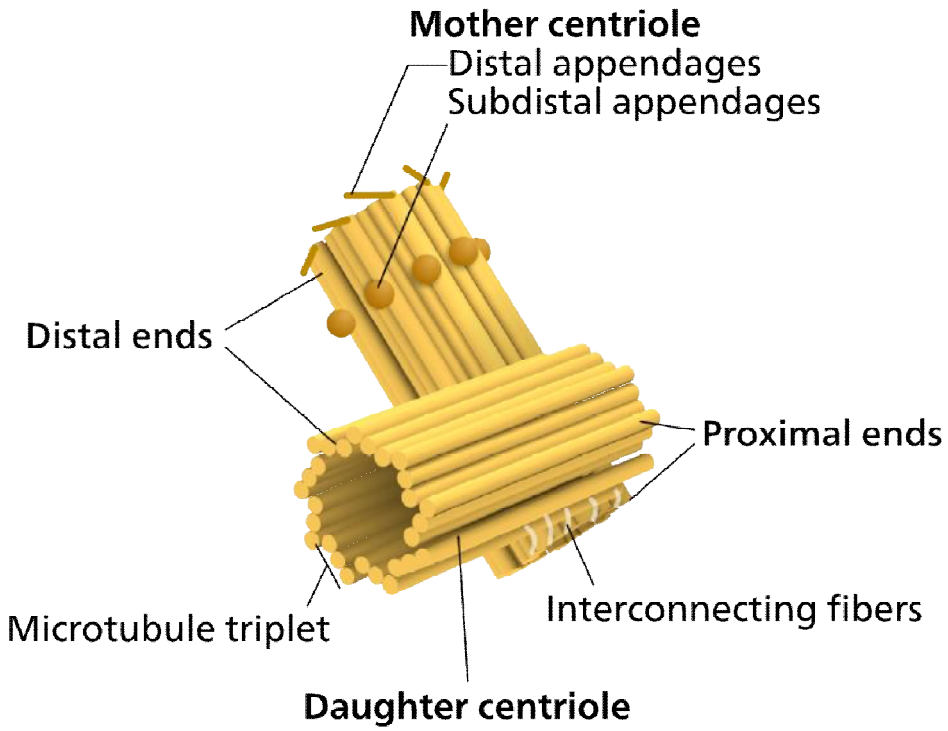
CENTROSOME

nucleating sites
(rings of **gama-tubulin**)



pair of centrioles




Mother centriole
Distal appendages
Subdistal appendages
Distal ends
Proximal ends
Microtubule triplet
Interconnecting fibers
Daughter centriole

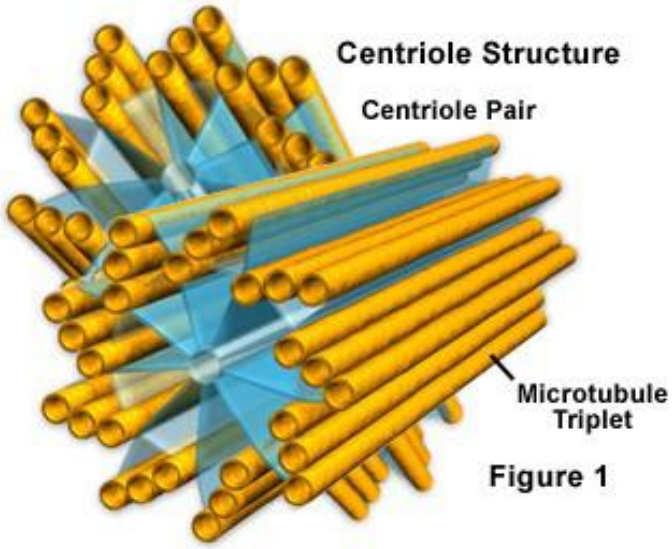
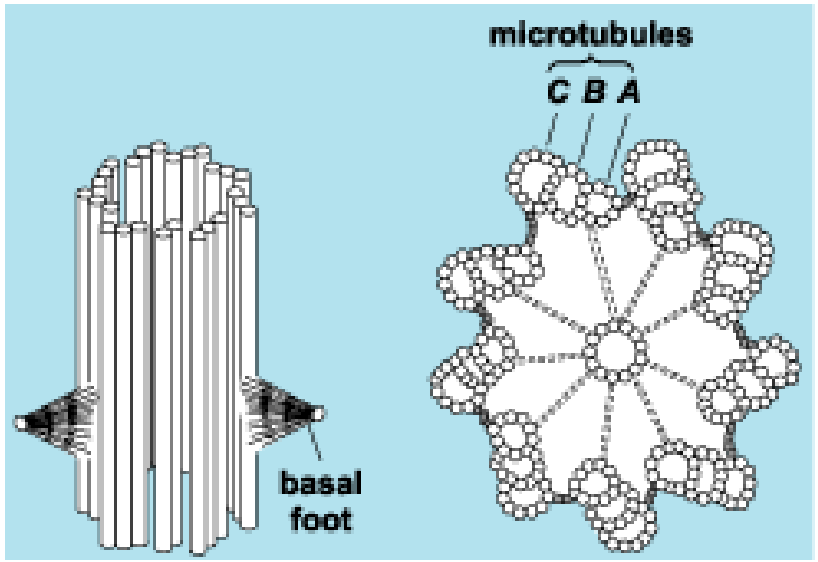

Centriole Structure
Centriole Pair
Microtubule Triplet

Figure 1


microtubules
C B A
basal foot

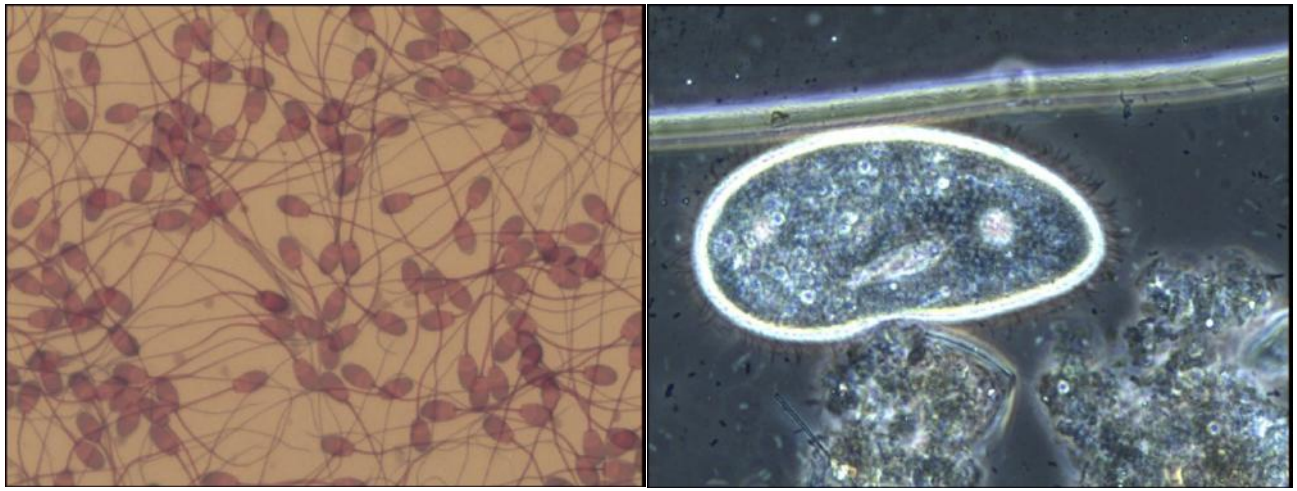
FLAGELA & SILIA

STRUKTUR:

- **Basal Body (Dasar/ Base)** – dibuat dari sentriol modifikasi (Procentriole)
- **Aksonema (Axoneme)** - Membentuk Inti (Core), mengandung :

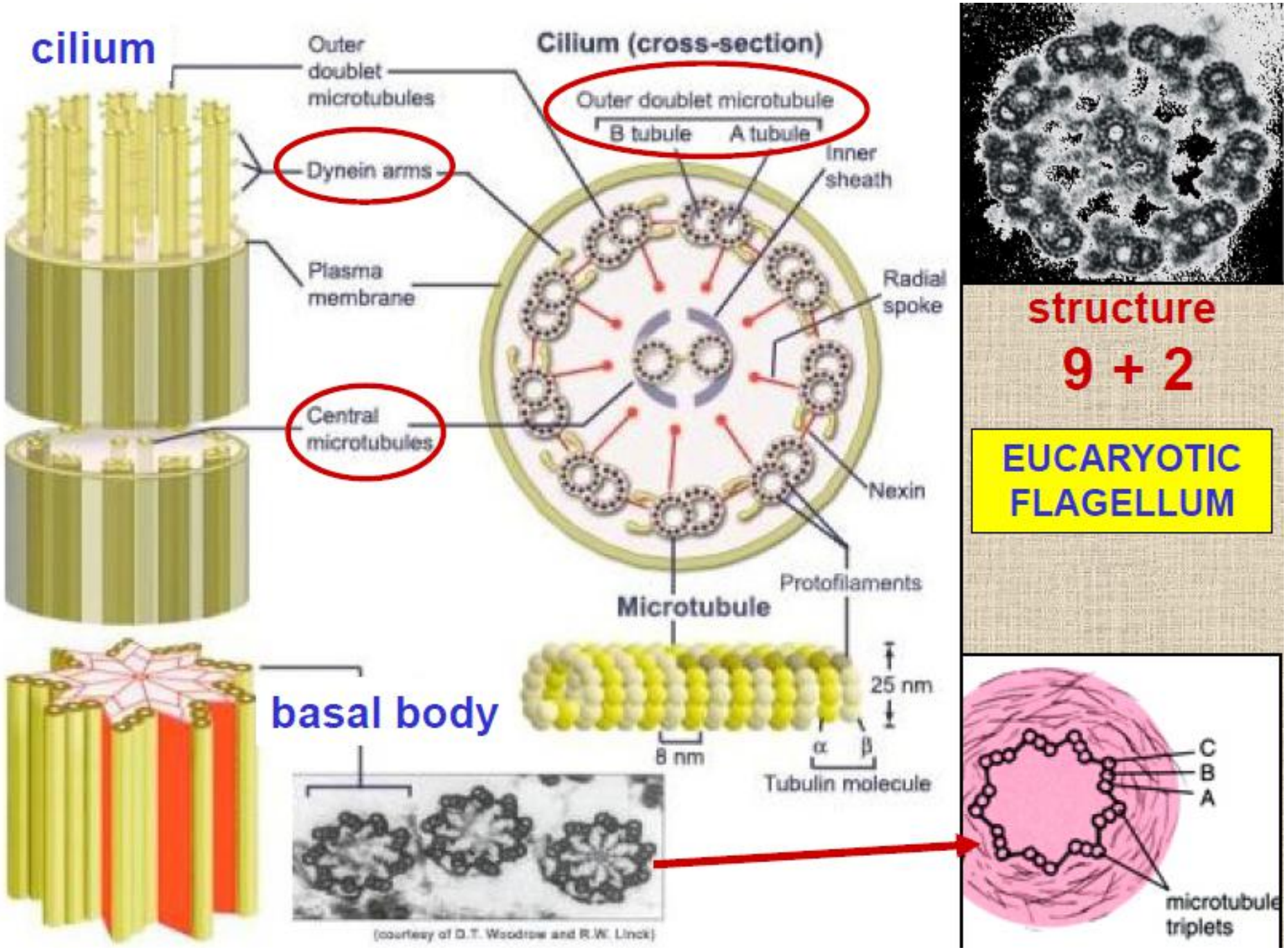
  2 Microtubulus tengah (Berpasangan)

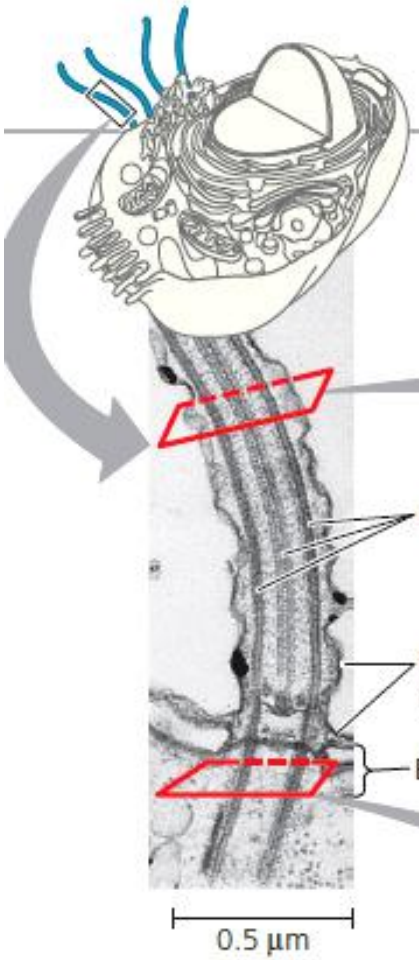
  9 *Periferal Doublets of Microtubule* (subunit A dan B) – terikat satu sama lain oleh **Nexin** dan ke bagian tengah (*central sheath*) oleh Jeruji Radial (Radial Spokes)
- **Dinein**



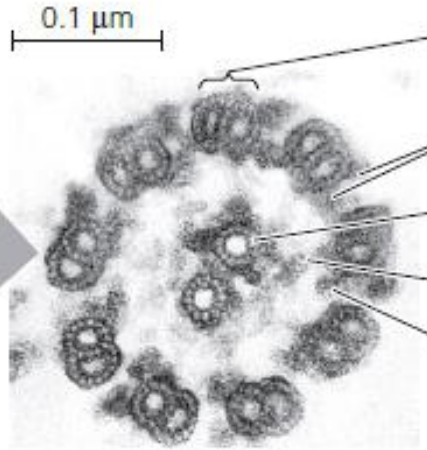
flagella = one per cell, 0.4 µm diameter, 100-200 µm long
cilia = many per cell, 0.4 µm diameter, 2-10 µm long

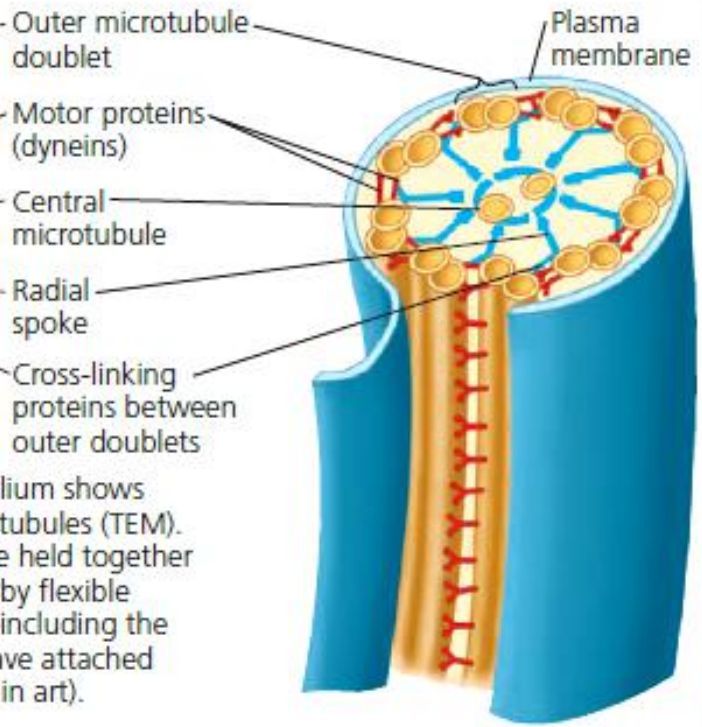
ANIMATION


cilium
Outer doublet microtubules
Dynein arms
Plasma membrane
Central microtubules
basal body
Cilium (cross-section)
Outer doublet microtubule
B tubule
A tubule
Inner sheath
Radial spoke
Nexin
Protofilaments
Microtubule
25 nm
8 nm
α
β
Tubulin molecule
(courtesy of D.T. Woodrow and R.W. Linck)
structure
9 + 2
EUCARYOTIC FLAGELLUM
C
B
A
microtubule triplets



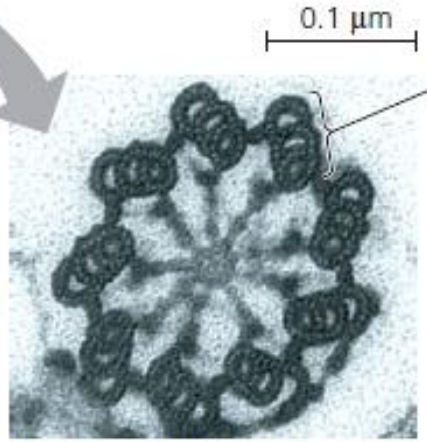
a) A longitudinal section of a motile cilium shows microtubules running the length of the membrane-sheathed structure (TEM).



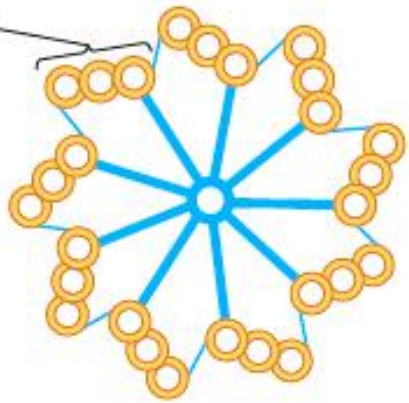


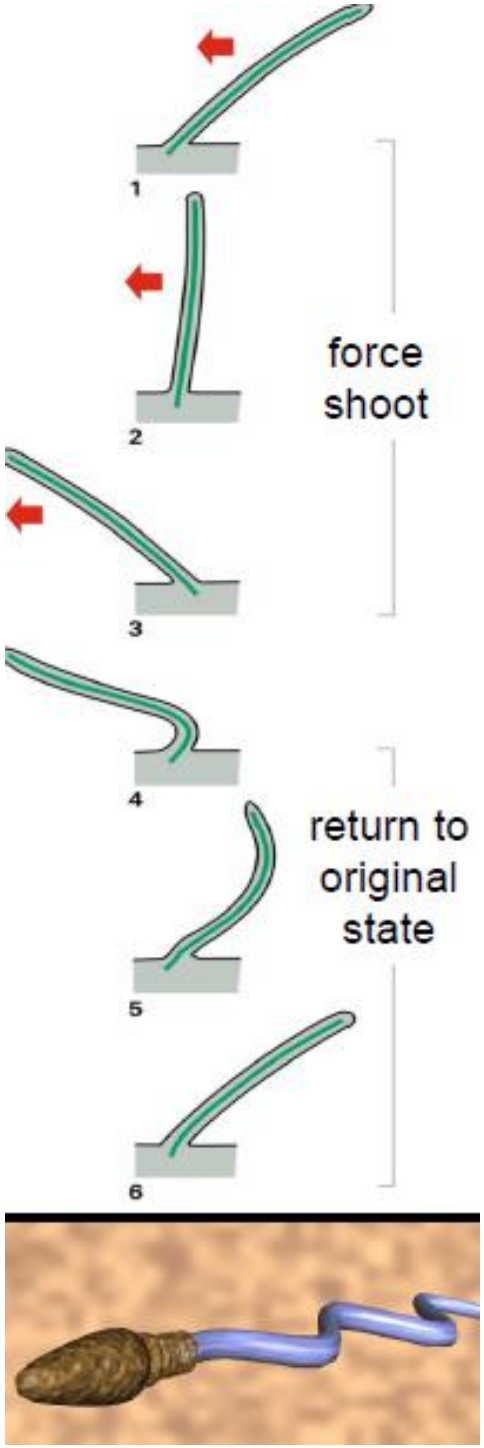
(b) A cross section through a motile cilium shows the "9 + 2" arrangement of microtubules (TEM). The outer microtubule doublets are held together with the two central microtubules by flexible cross-linking proteins (blue in art), including the radial spokes. The doublets also have attached motor proteins called dyneins (red in art).

c) Basal body: The nine outer doublets of a cilium or flagellum extend into the basal body, where each doublet joins another microtubule to form a ring of nine triplets. Each triplet is connected to the next by nontubulin proteins (thinner blue lines in diagram). This is a "9 + 0" arrangement: The two central microtubules are not present because they terminate above the basal body (TEM).



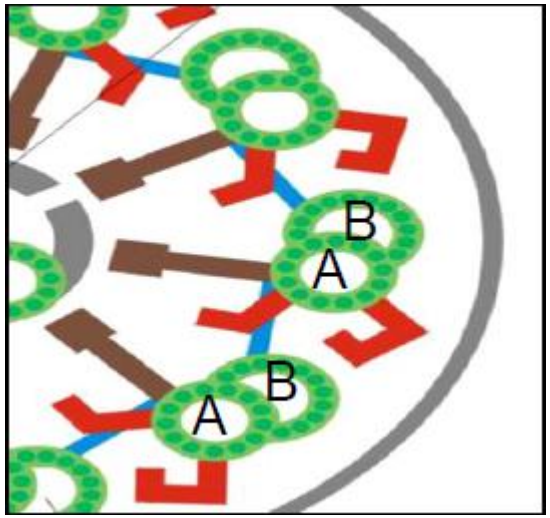
Cross section of basal body

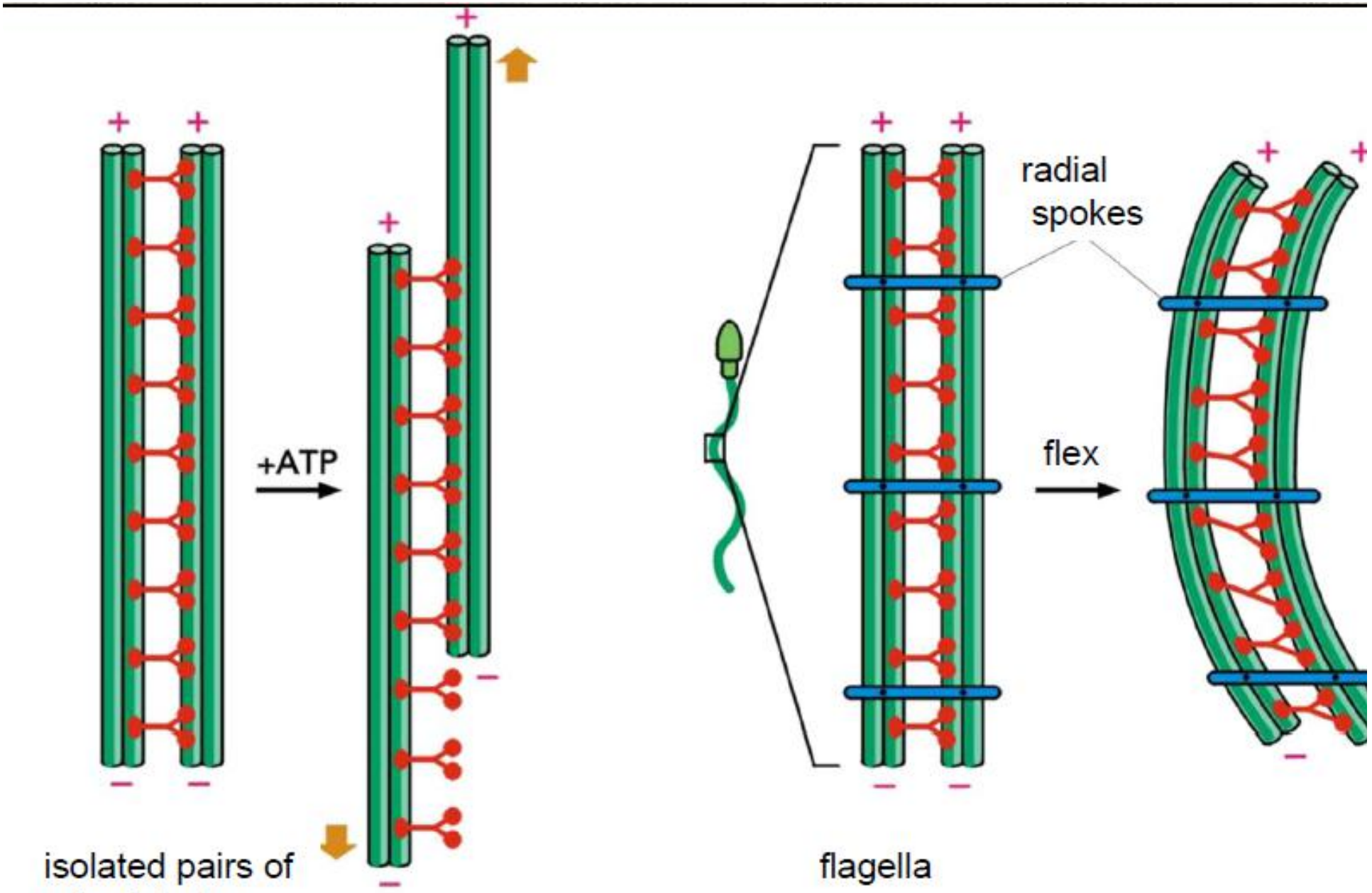




Prinsip Pergerakan Flagel dan Silia

- Bagian ekor **Dinein** terikat pada **subunit A doublet mikrotubulus**
- Bagian motor **Dinein** berinteraksi/ kontak dengan subunit B dari **doublet mikrotubulus sebelahnya menyebabkan hidrolisis ATP**
- Aktivasi motor mengubah formasinya
- Karena doublet mikrotubulus terikat oleh **Radial Spoke**, sehingga tidak meluncur (**slide**) tetapi **Flex**

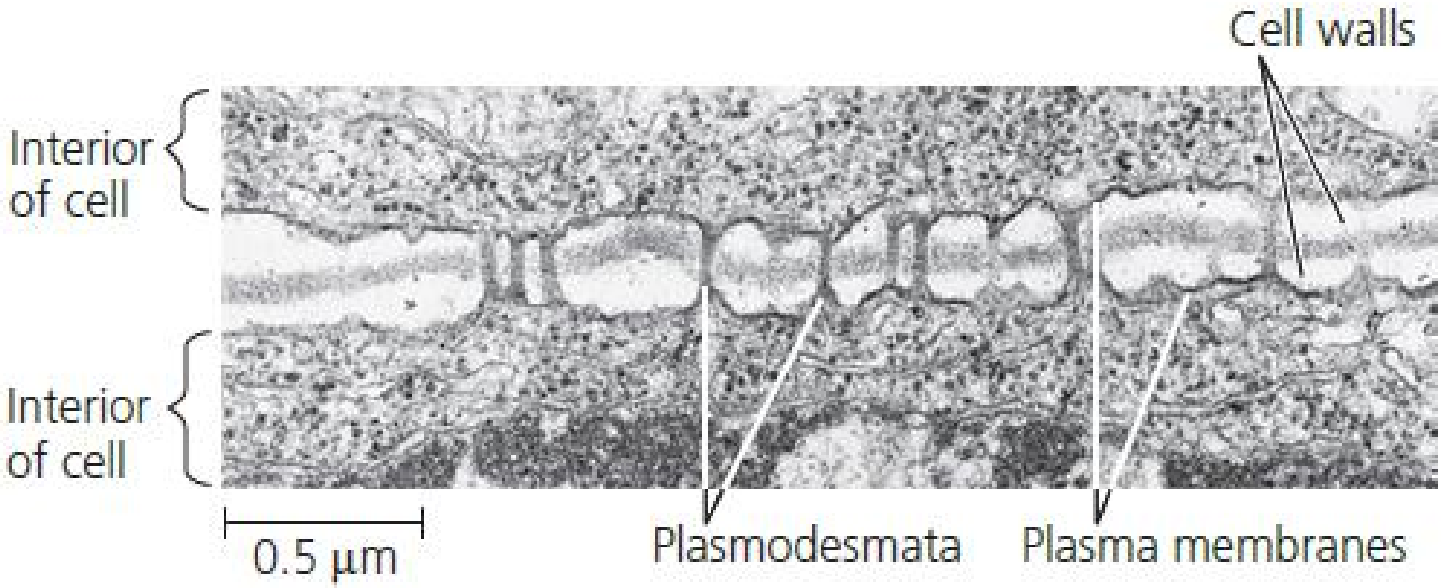




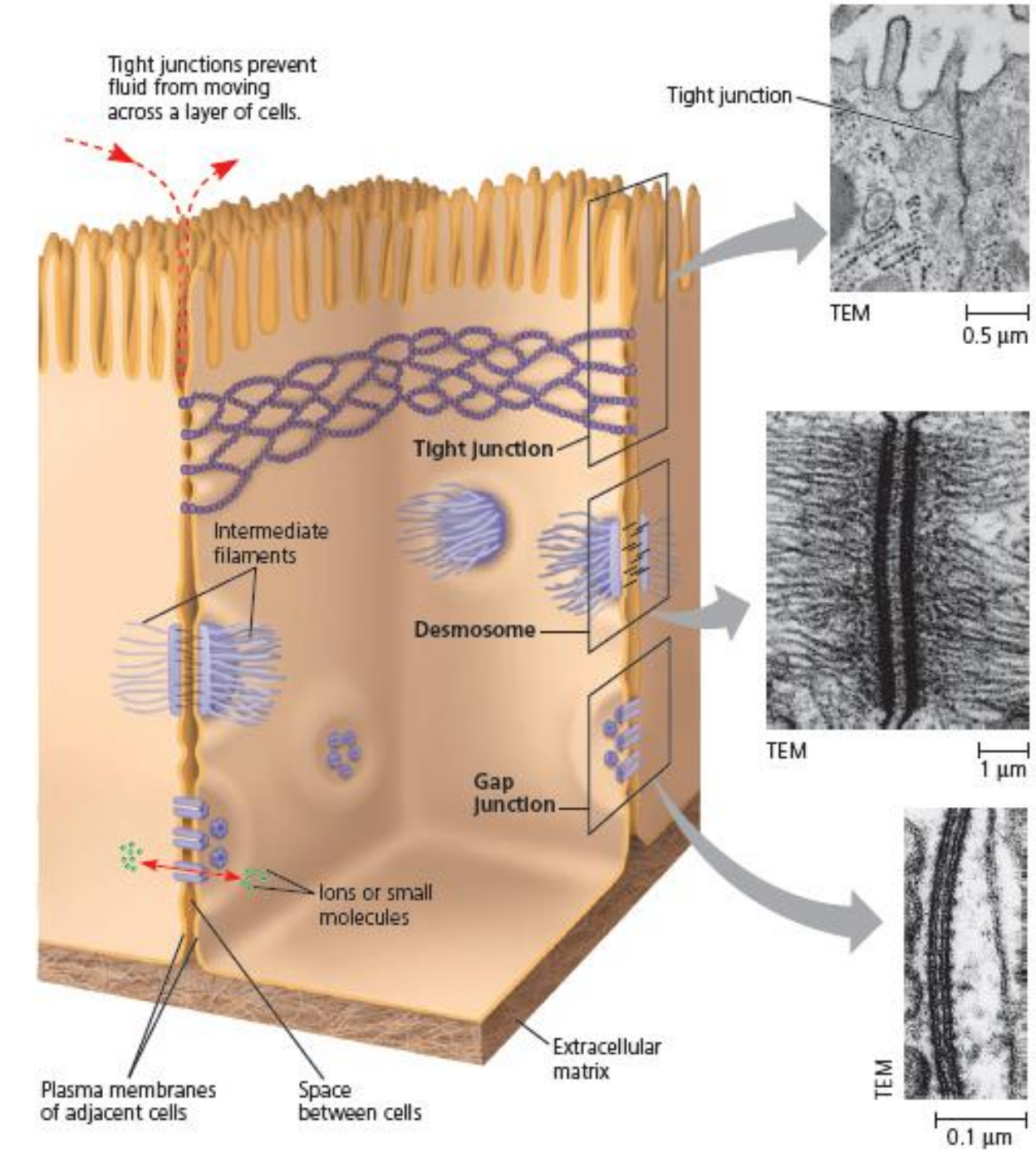
sliding of microtubules

flexion of microtubules

SAMBUNGAN ANTAR SEL



Sambungan pada tumbuhan



SAMBUNGAN KETAT (*Tight Junction*)

Membran sel yg bersebelahan saling menekan kuat & disatukan oleh protein spesifik, mencegah kebocoran cairan ekstraseluler, ex: pada kelenjar keringat

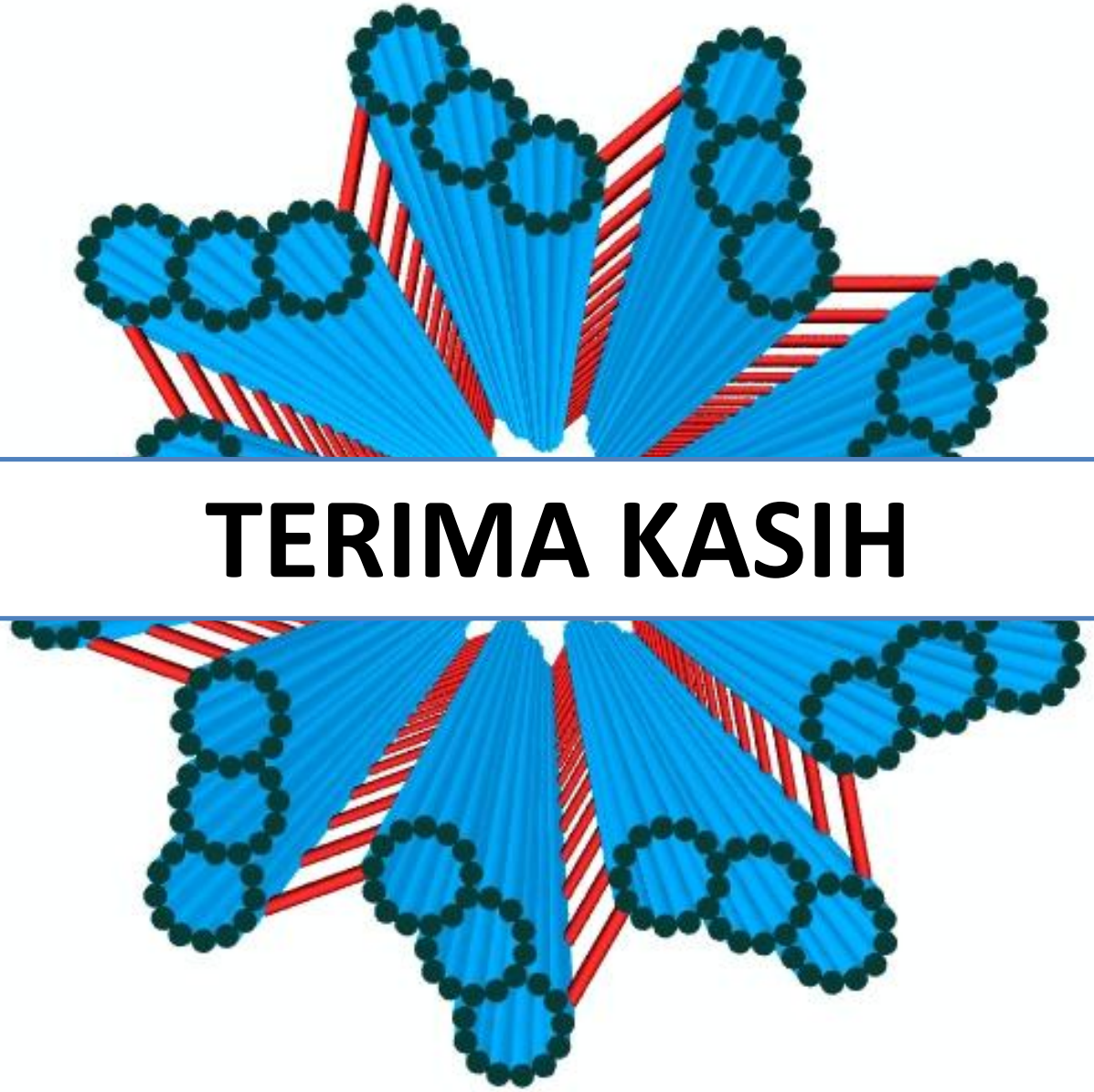
DESMOSOM (Sambungan penambat - *Anchoring Junction*)

Seperti sekrup yg menyambungkan sel2 mjd lembaran2 kuat. Filamen intermediat dr protein keratin menambatkan desmosom dalam sitoplasma. Ex: Desmosom melekatkan sel2 otot, otot robek = koyaknya desmosom

SAMBUNGAN CELAH (sambungan komunikasi, *Gap Junction*)

Menyediakan saluran sitoplasma dari satu sel ke sel lain yang bersebelahan (**mirip plasmodesmata**). Terdapat protein2 membran pada celah/ pori yg dpt dilewati ion, asam amino untuk komunikasi

Ex: otot jantung, embrio hewan



TERIMA KASIH