Biological Frameworks for Engineers

ME 411 / ME 511

Biological Frameworks for Engineers

UNIVERSITY OF WASHINGTON

Class Organization

- Exam 1 due today
- Homework 4 due on Fri

Biological Frameworks for Engineers

ME 411 / ME 511

Cell Cytoskeleton

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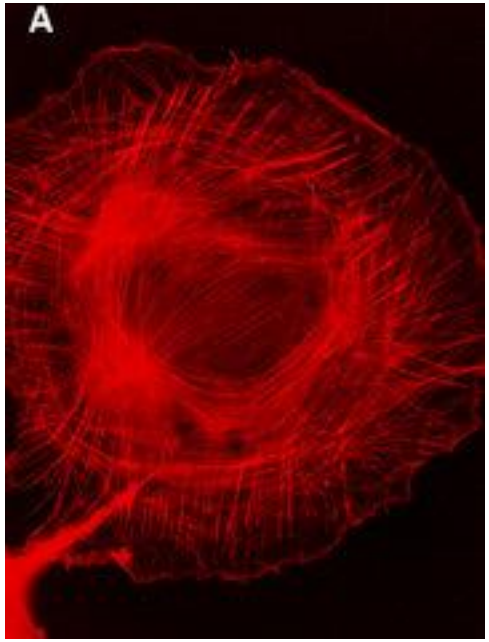
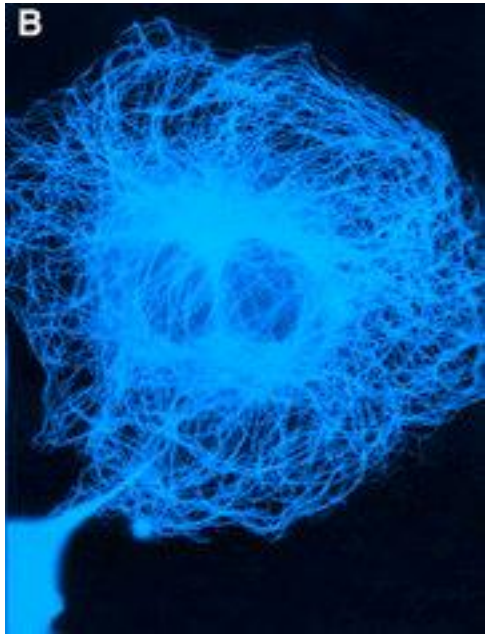
Cytoskeleton

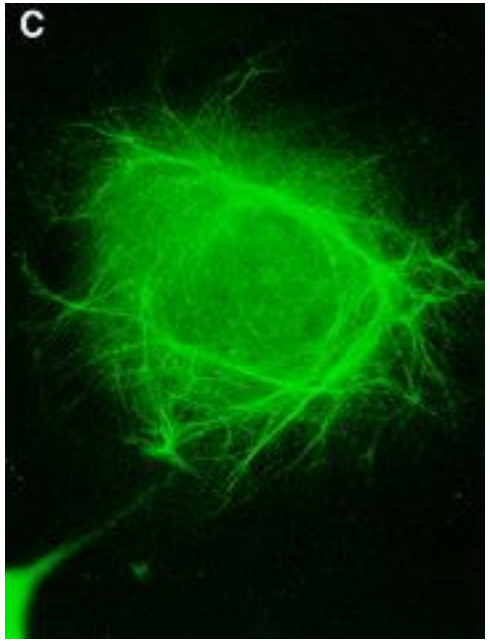
- Three fundamental filaments



Actin



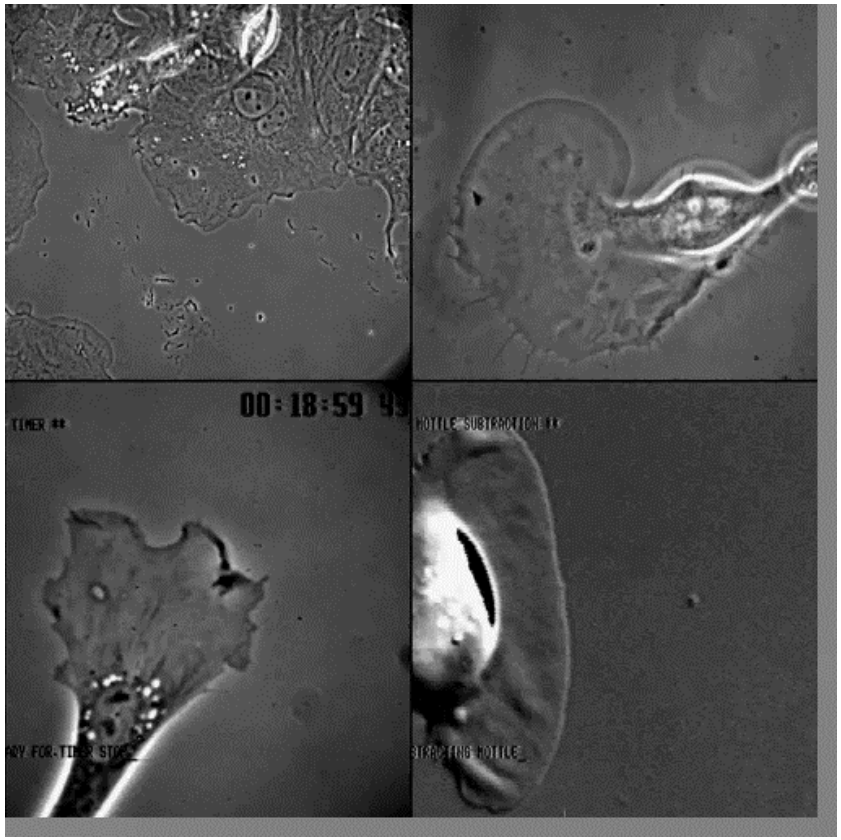
Microtubules (MT)



Intermediate Filaments (IF)

Cells Have Dynamic Structure

- Cell Crawling
- Phagocytosis
- Cytokinesis
- Muscle contraction
- Gastrulation

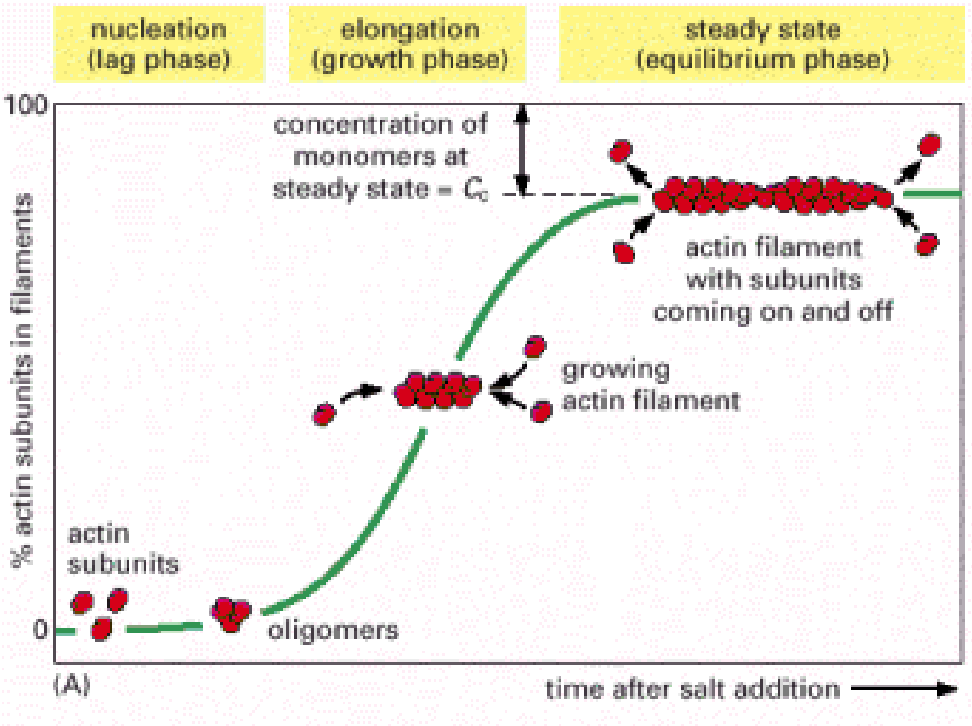


Top left: mouse fibroblasts in scratch wound assay (3h).
Top right: mouse melanoma cell (20min).
Bottom left: a chick fibroblasts (2h).
Bottom right: trout epidermal keratocyte (4min).

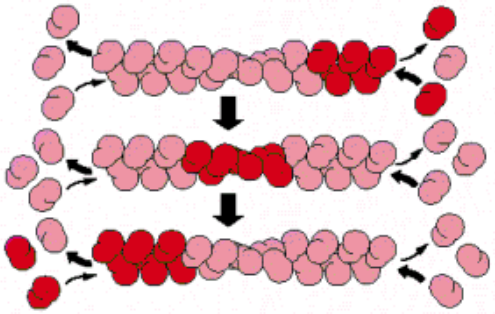
Polymerization of Subunits

- Assembly/disassembly of monomers subunits

[G-Actin]
[α-tublin & β-tubulin]
[desmin or vimentin]



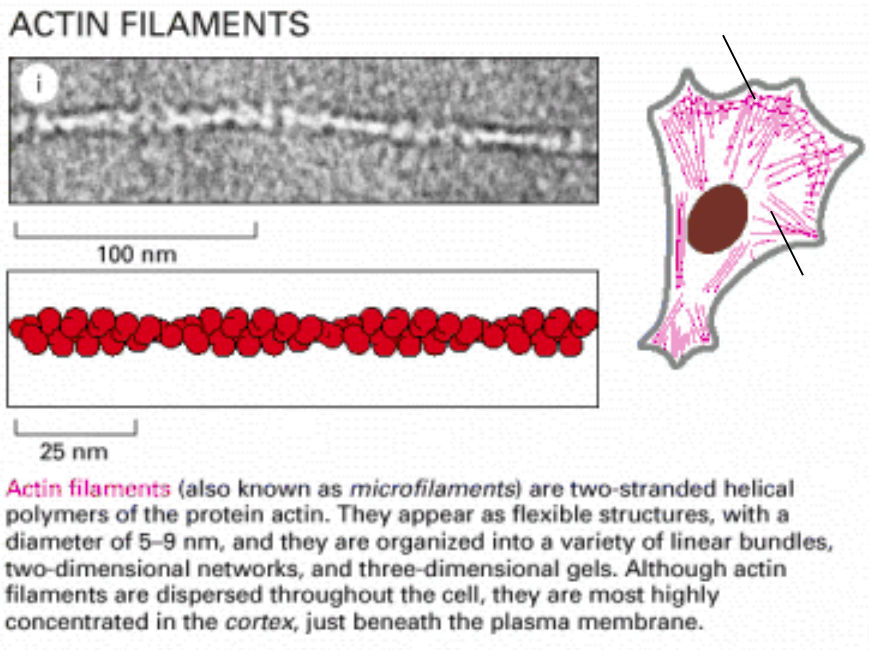
Treadmilling is a flux of subunits but maintains a steady-state length.



Actin

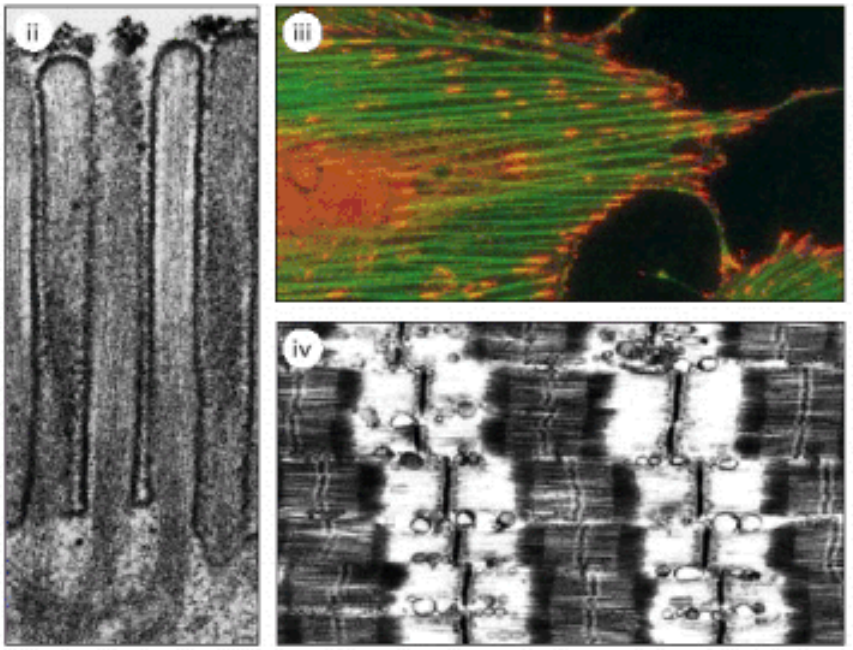
- Most versatile and abundant protein of cells
- G-actin: 375 amino acids, 42 kDa

Stress Fibers &
Focal Adhesions



Actin filaments (also known as *microfilaments*) are two-stranded helical polymers of the protein actin. They appear as flexible structures, with a diameter of 5–9 nm, and they are organized into a variety of linear bundles, two-dimensional networks, and three-dimensional gels. Although actin filaments are dispersed throughout the cell, they are most highly concentrated in the *cortex*, just beneath the plasma membrane.

Micrographs courtesy of Roger Craig (i and iv); P.T. Matsudaira and D.R. Burgess (ii); Keith Burridge (iii)

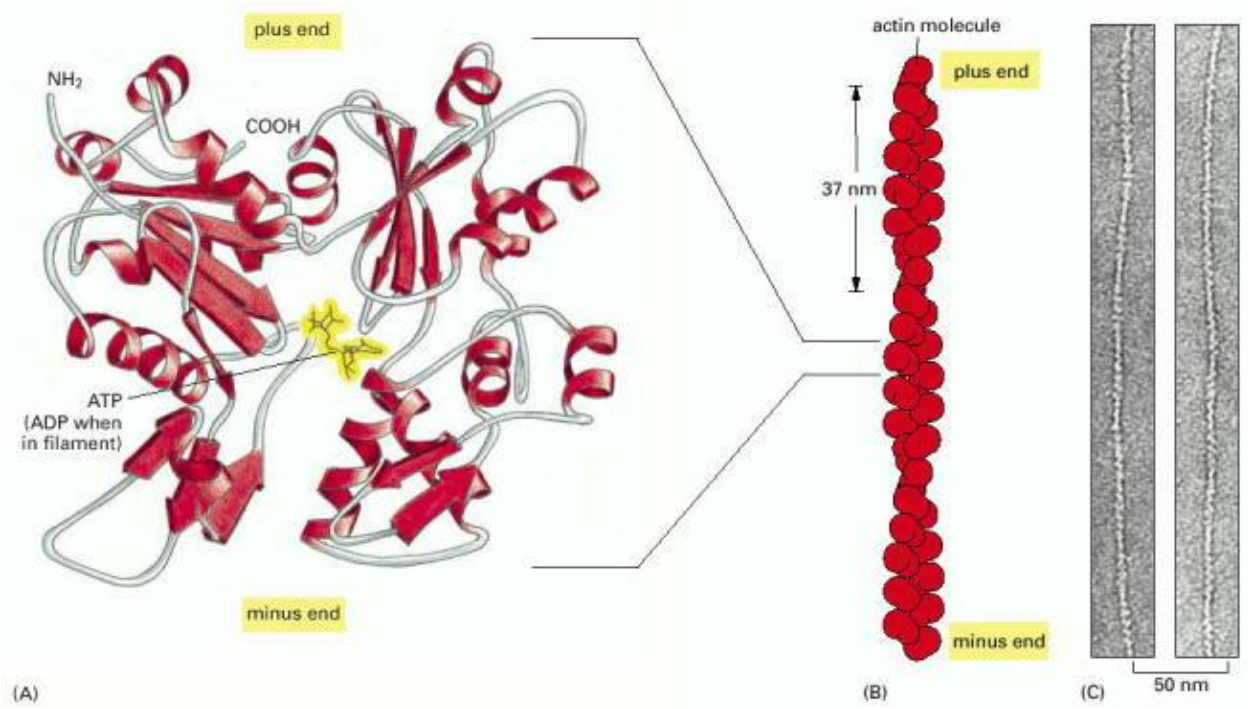


Microvilli

Myofibrils

Actin Assembly

- Assembly is regulated by ATP binding.



- Six major isoforms of actin found in different tissue that differ by their N-terminal sequence

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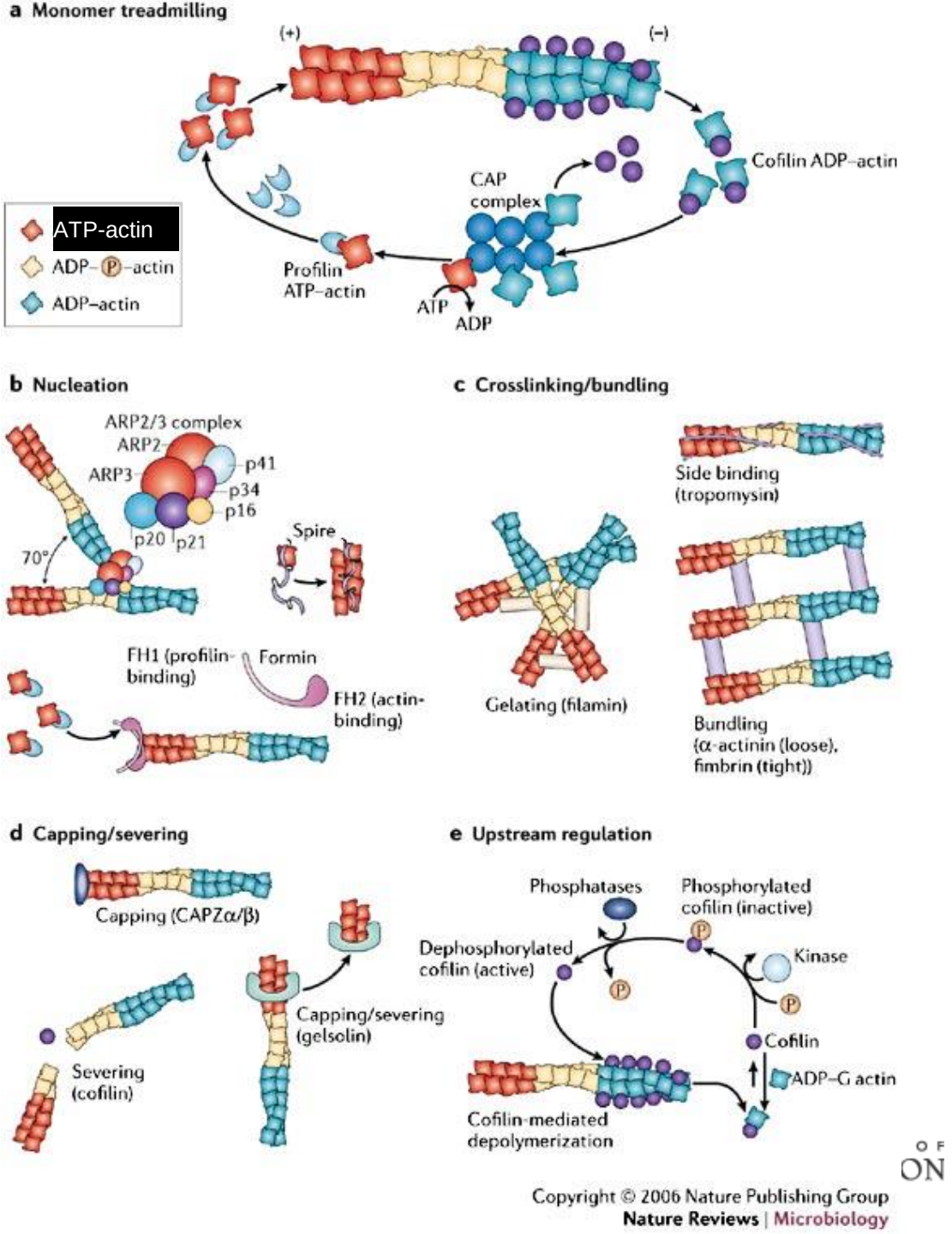
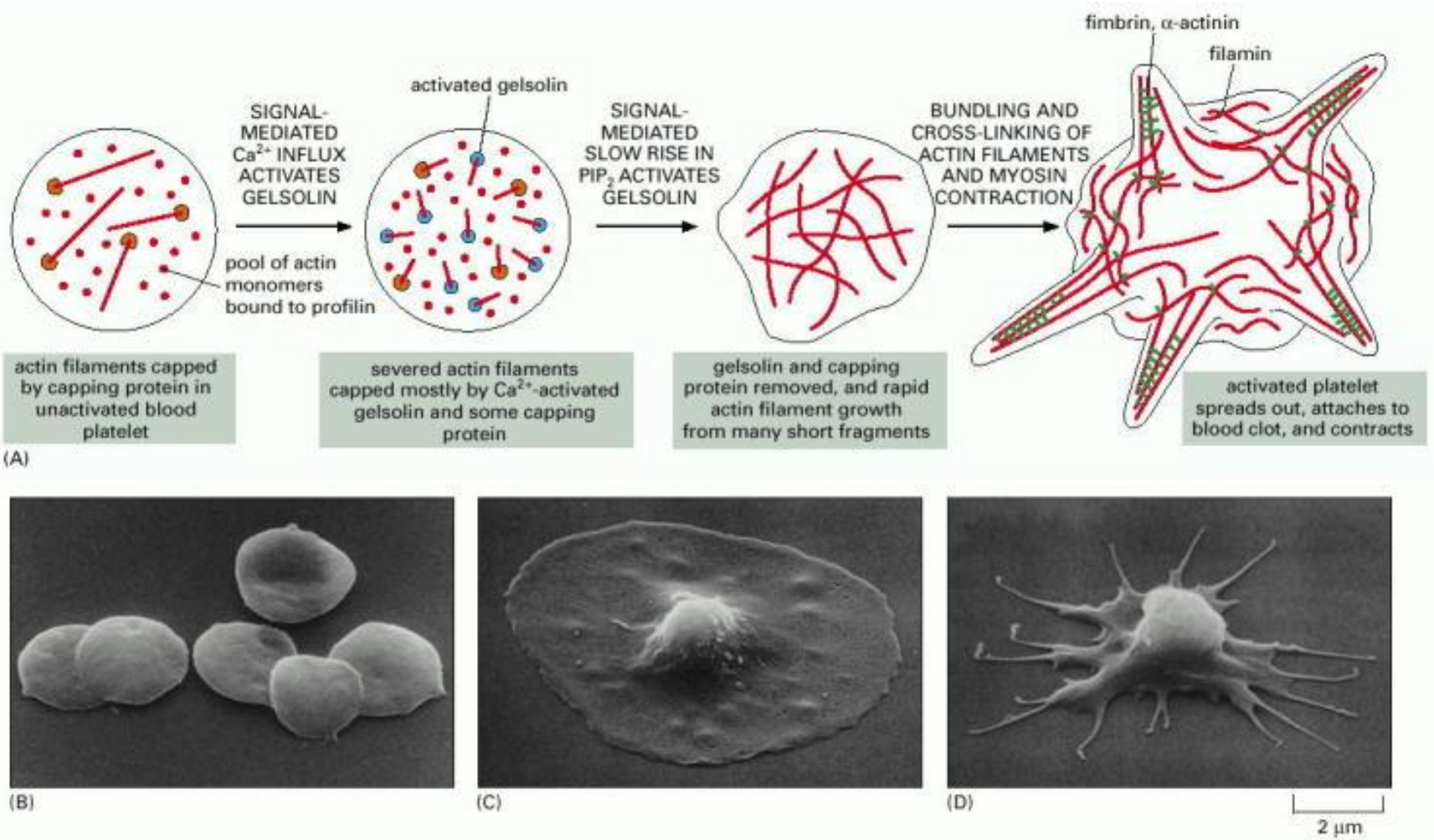
Actin Binding Proteins

A) Treadmilling
B) Nucleation
C) Crosslinking
D) Disruption
E) Regulation

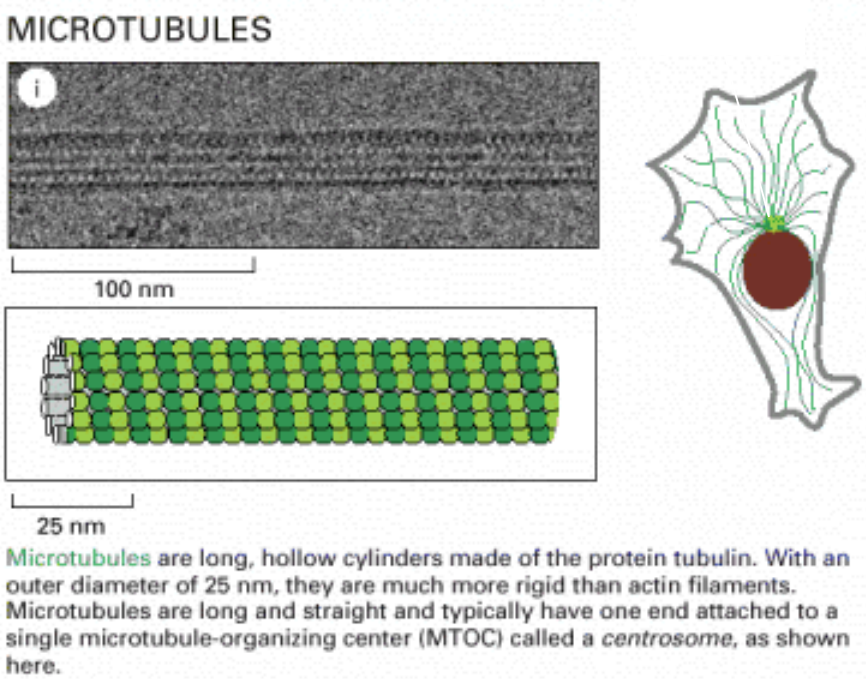


Rapid response of actin

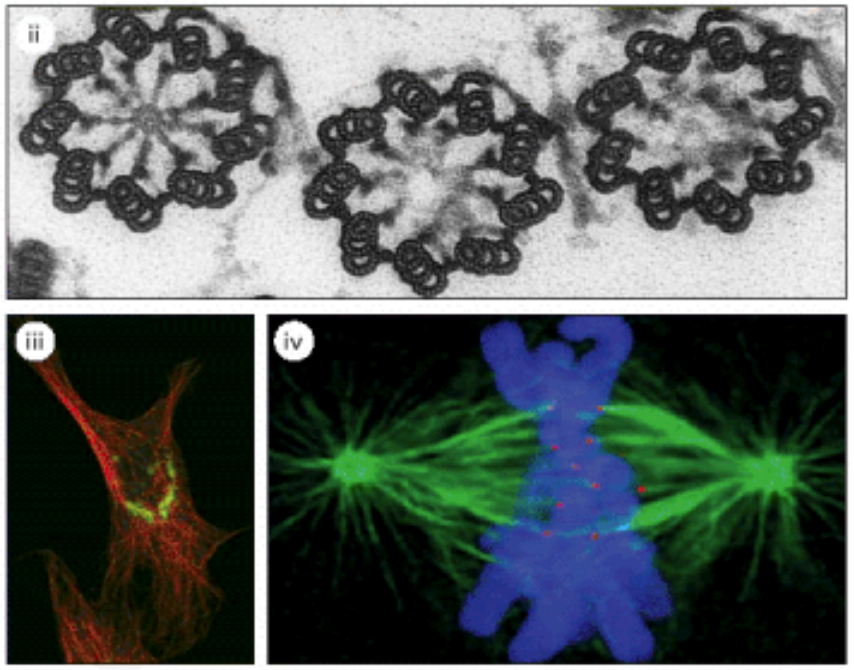


Microtubules

- Hollow, stiff filaments that direct traffic
- Tubulin: 50 kDa



Cilia (axoneme)

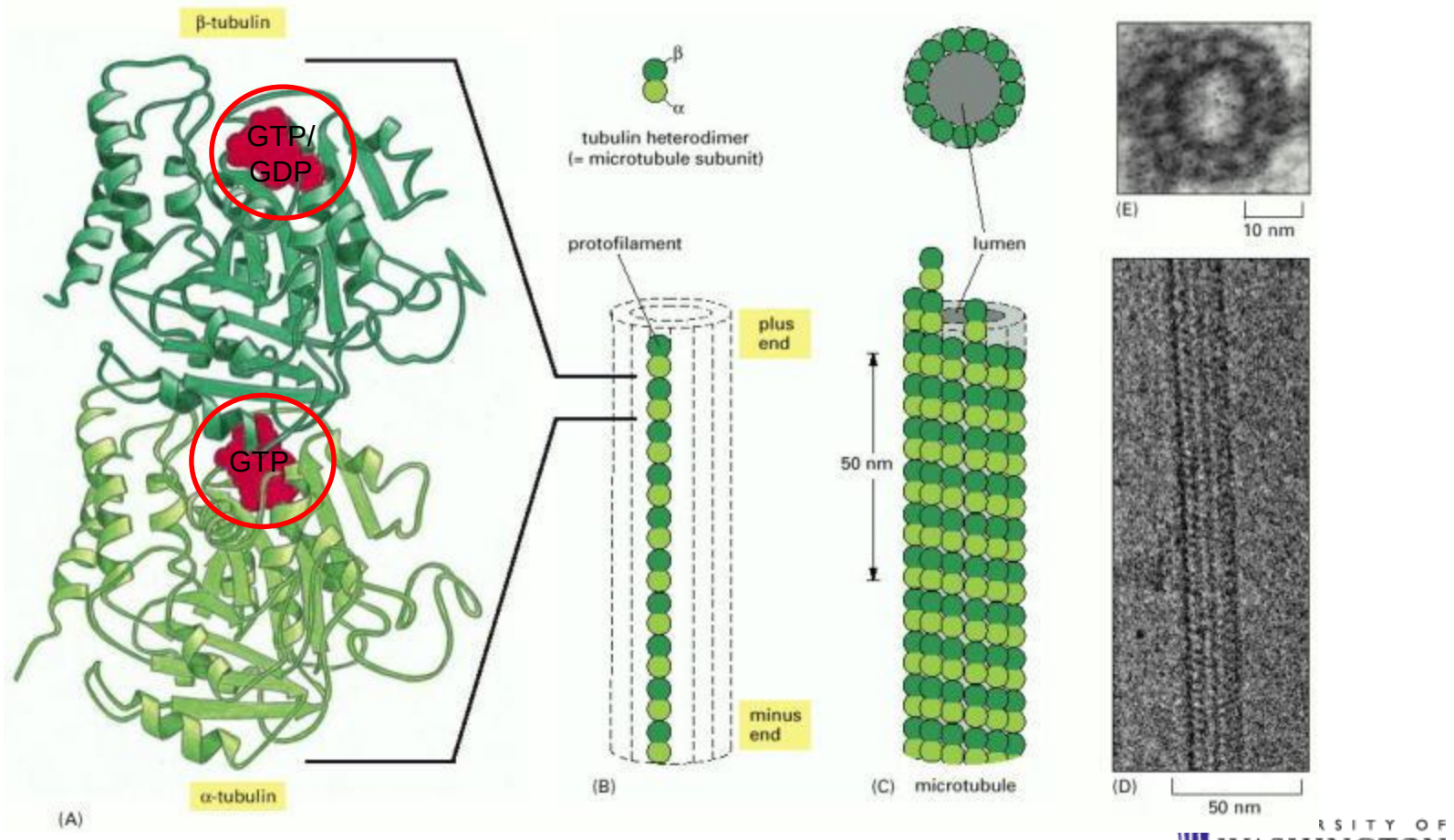


Star-Like

Mitotic Spindle

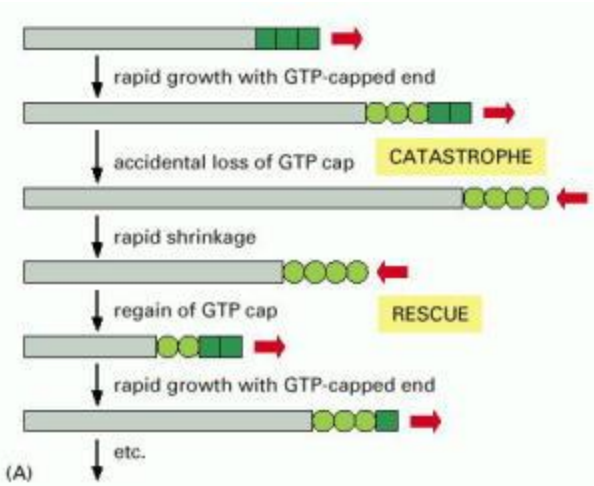
Microtubule Assembly

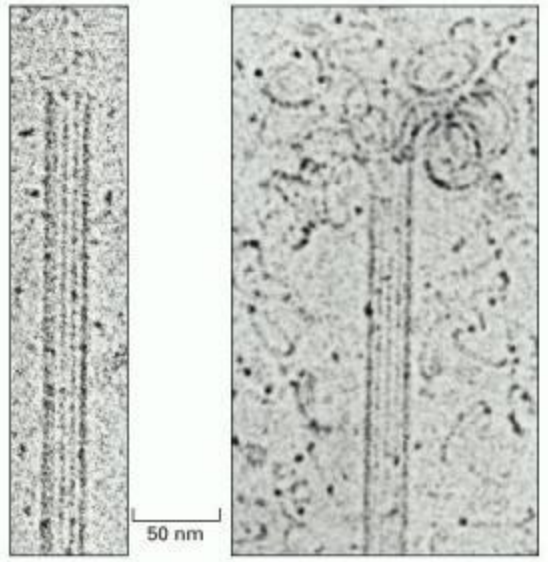
- Heterodimers of α-tubulin and β-tubulin

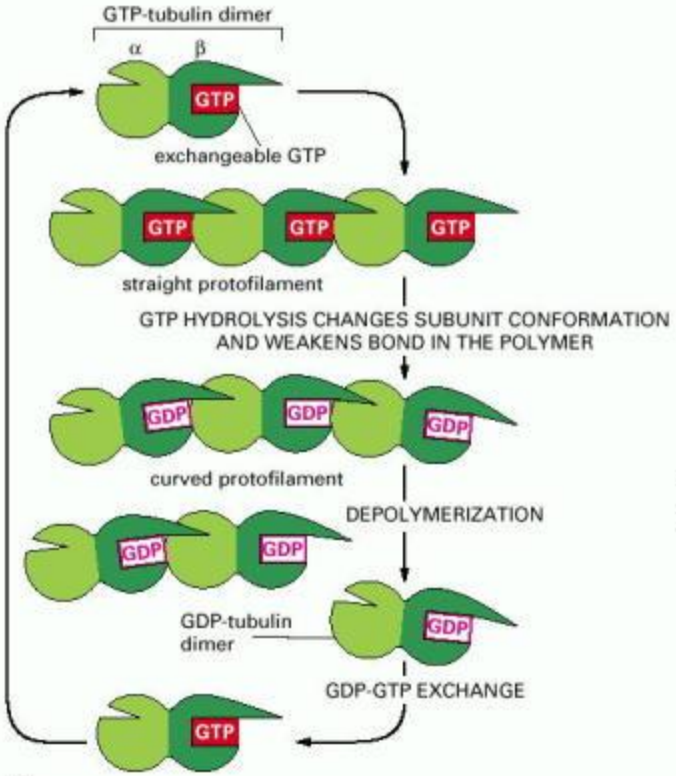


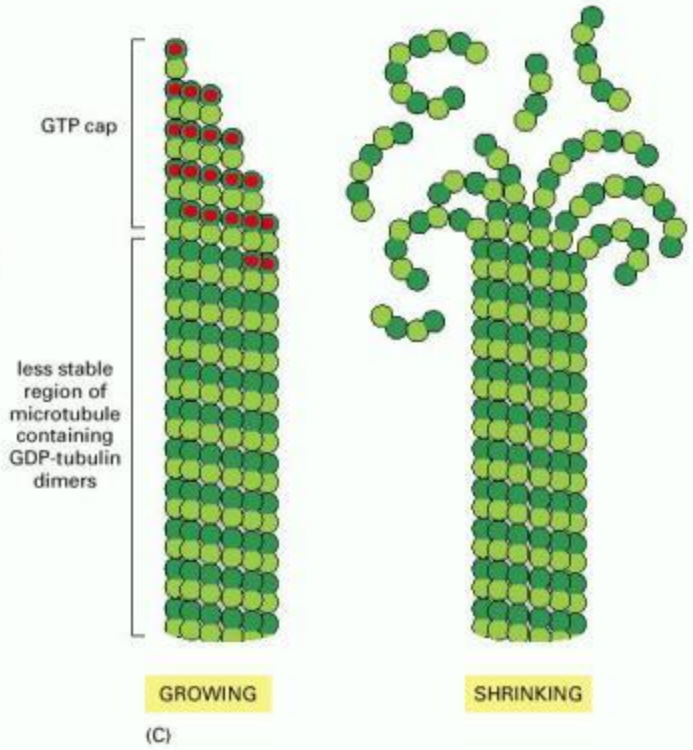
MT Instability

Free ends abruptly alternate between growing and shrinking phases.



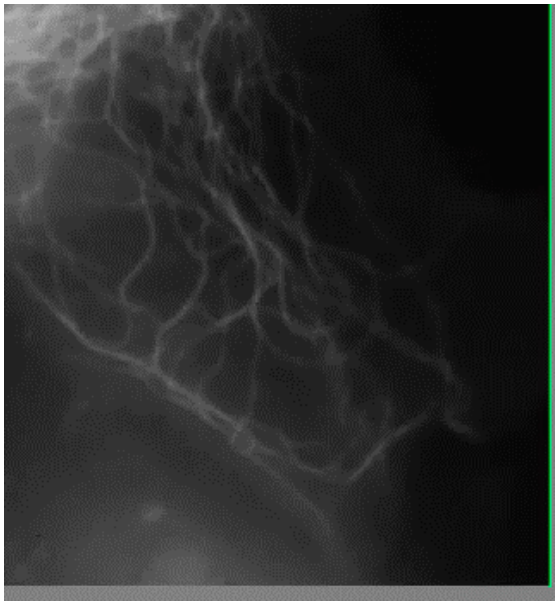






Microtubule Instability

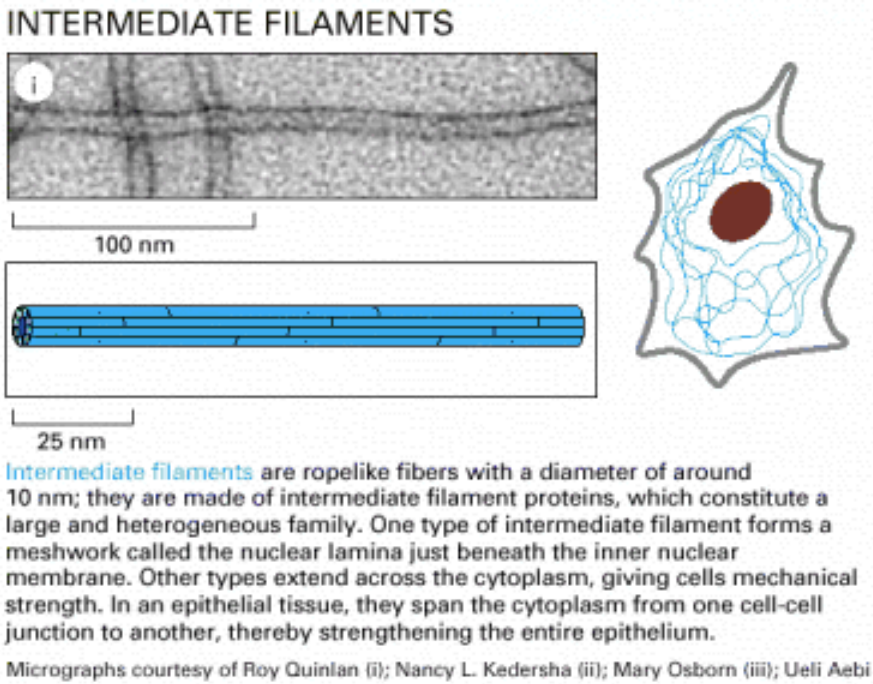
CHO Cytoplast with Centrosome

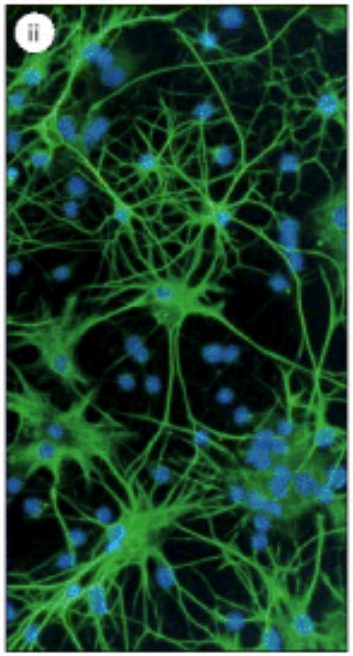


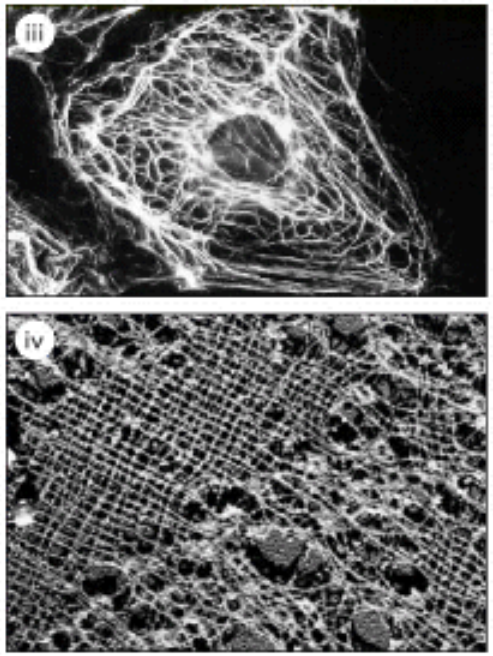
Intermediate Filaments

- Defines cell shape and mechanical properties
- Major types: lamins, vimentin, desmin, keratins, neurofilaments.

Strength (vimentin, desmin)



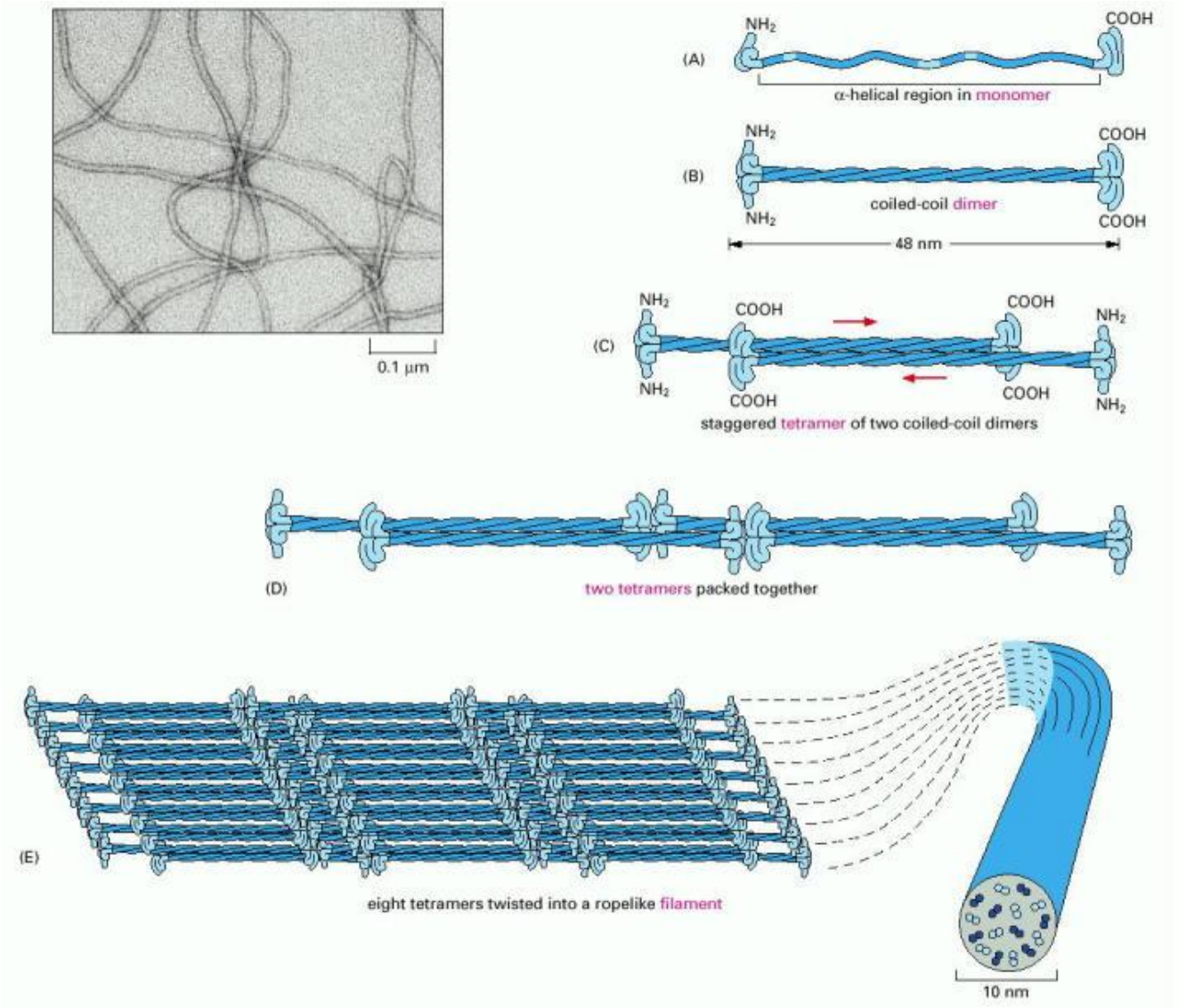




Axons (neurofilaments)

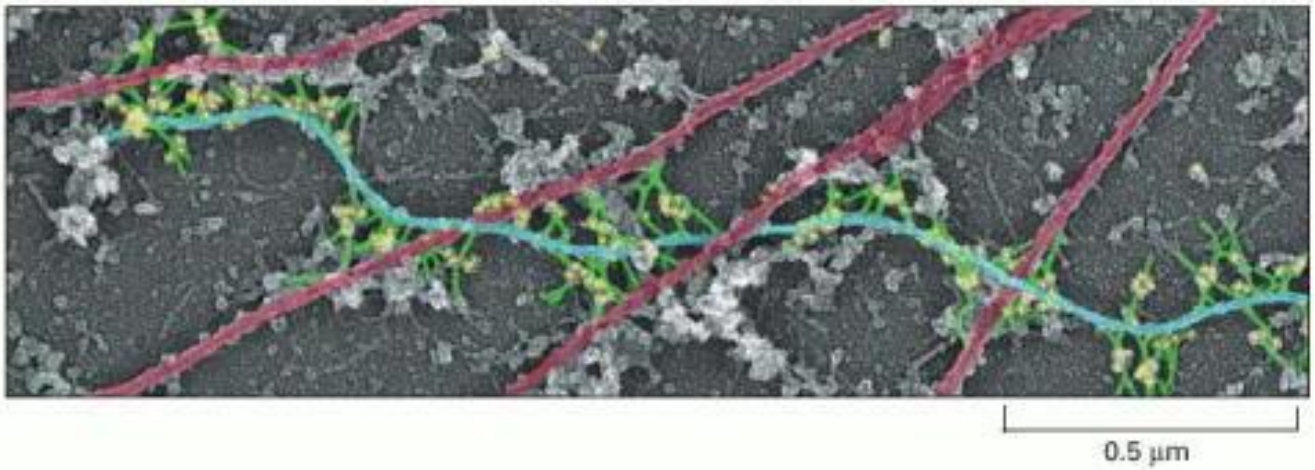
Nuclear Lamina

IF Assembly


0.1 μm
(A)
NH2
COOH
α-helical region in monomer
(B)
coiled-coil dimer
48 nm
(C)
staggered tetramer of two coiled-coil dimers
(D)
two tetramers packed together
(E)
eight tetramers twisted into a ropelike filament
10 nm

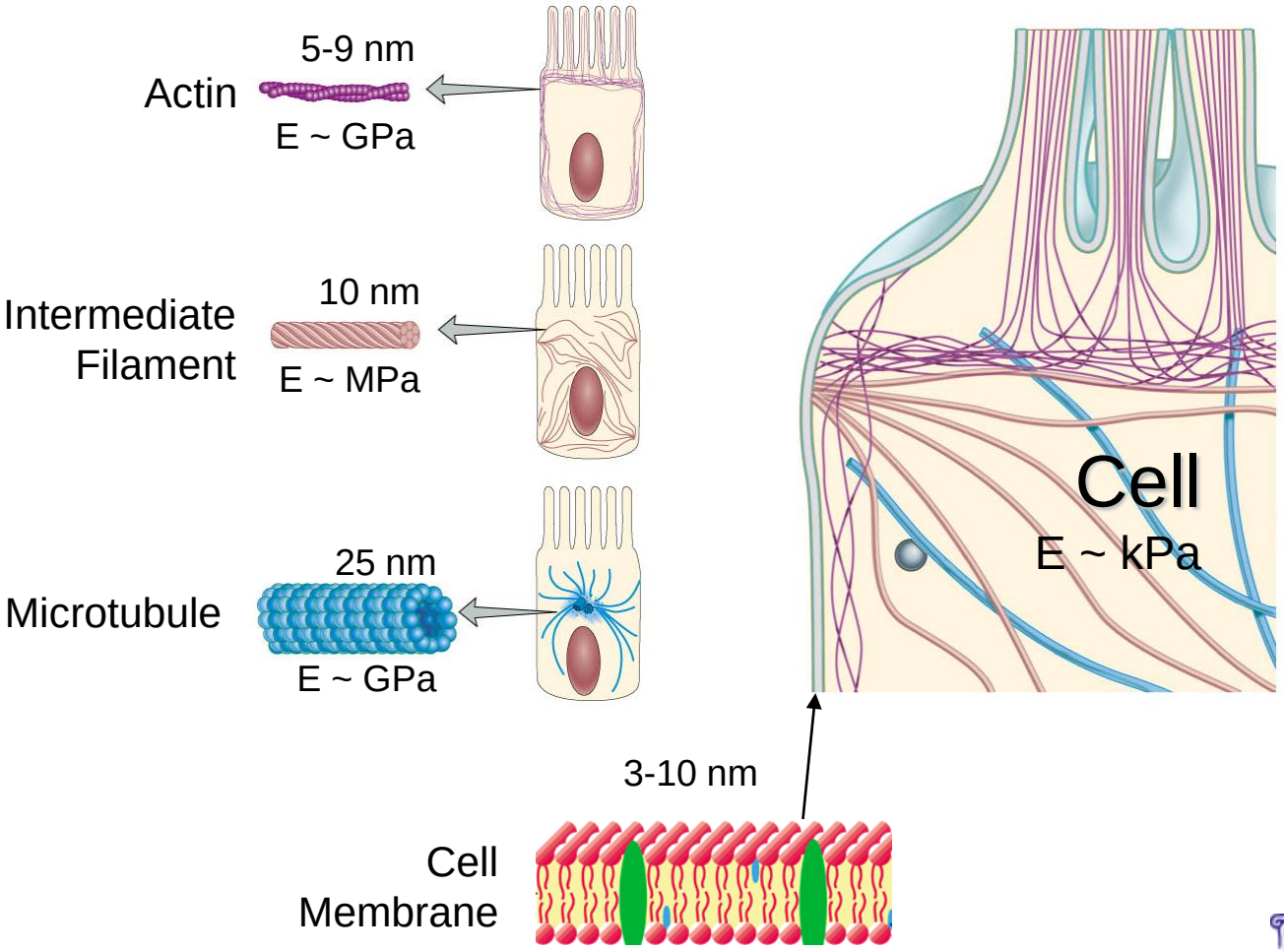
Cytoskeletal Cross-linking

- Intermediate filaments (blue), plectin (green), Microtubules (red), anti-plectin labelled gold particles (yellow)

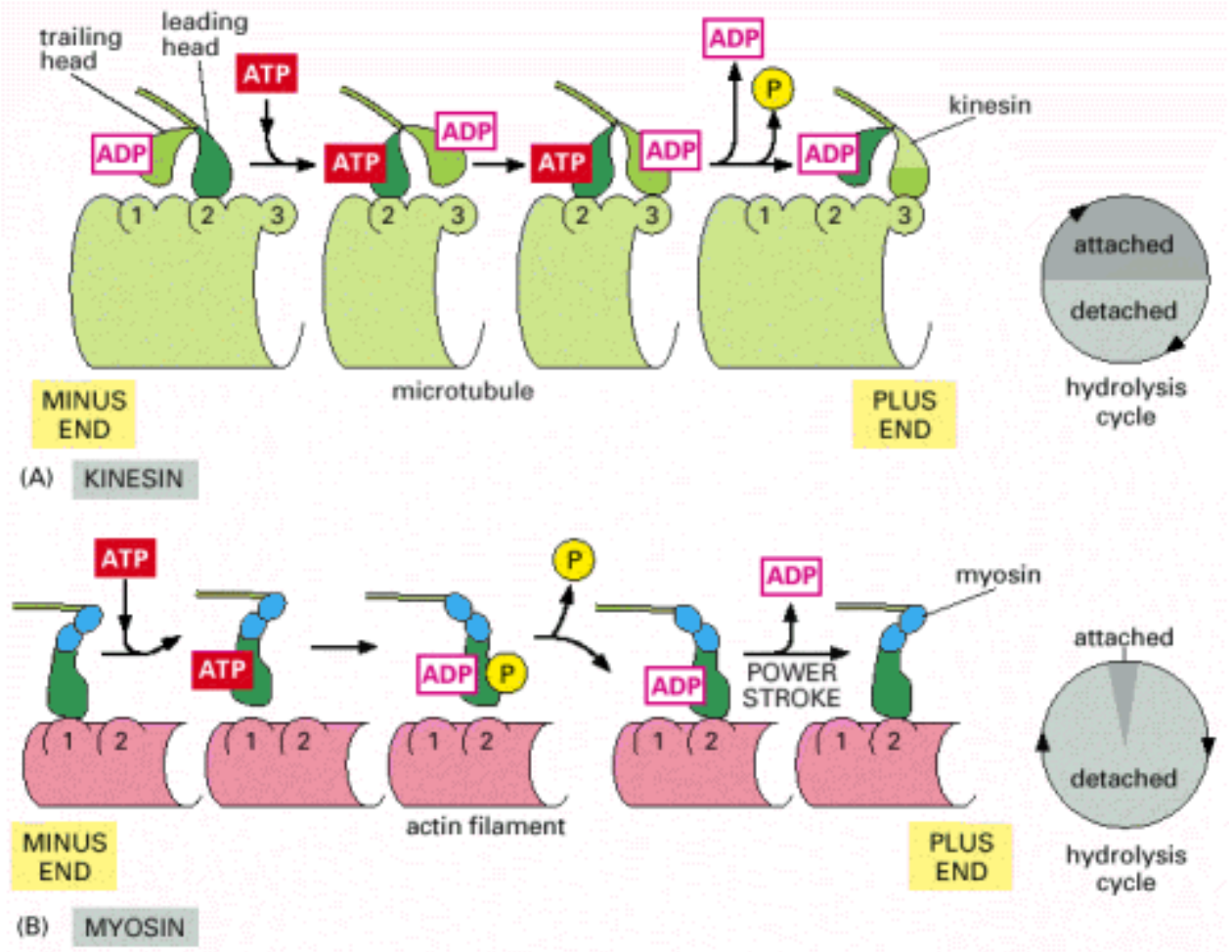


Cytoskeletal Crosslinking

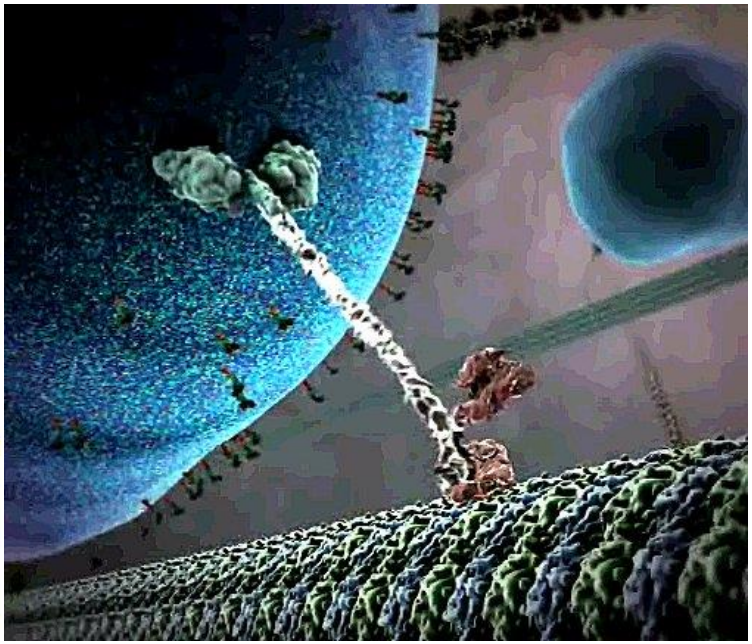
- Stiff polymer filaments form a soft cell

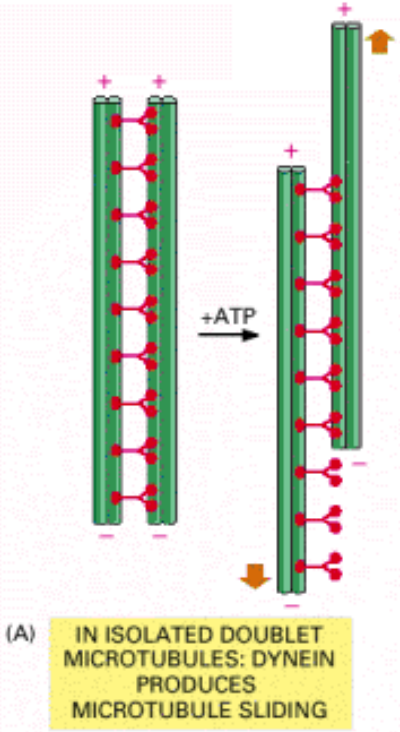


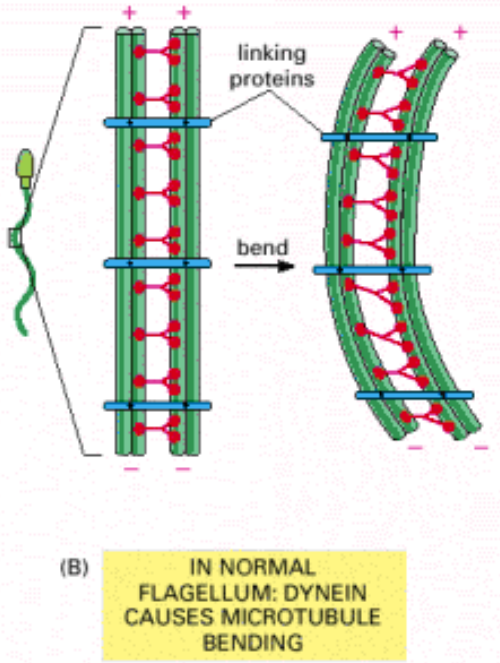
Molecular Motors



Kinesin & Dynein







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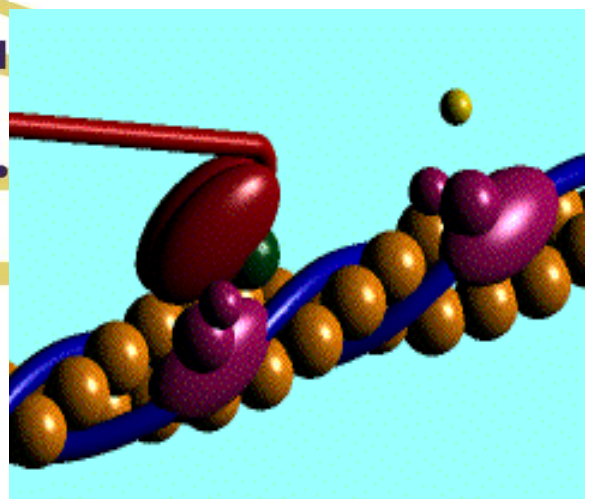
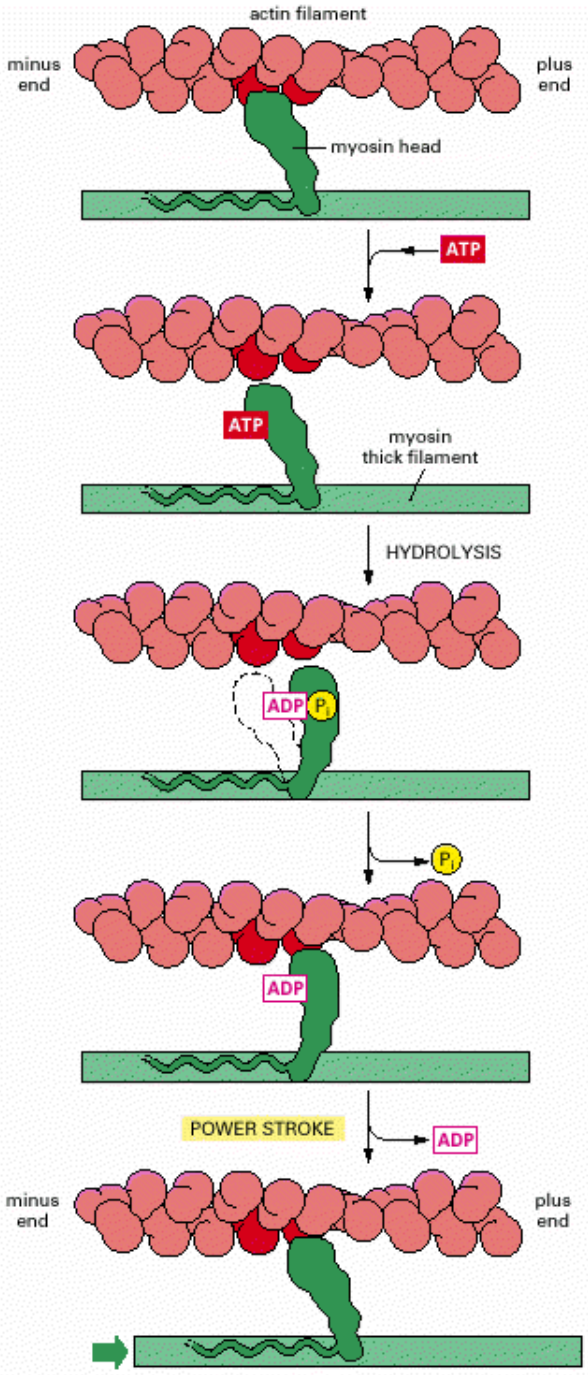
Myosin





ATTACHED At the start of the cycle shown in this figure, a myosin head lacking a bound nucleotide is locked tightly onto an actin filament in a *rigor* configuration (so named because it is responsible for *rigor mortis*, the rigidity of death). In an actively contracting muscle, this state is very short-lived, being rapidly terminated by the binding of a molecule of ATP.

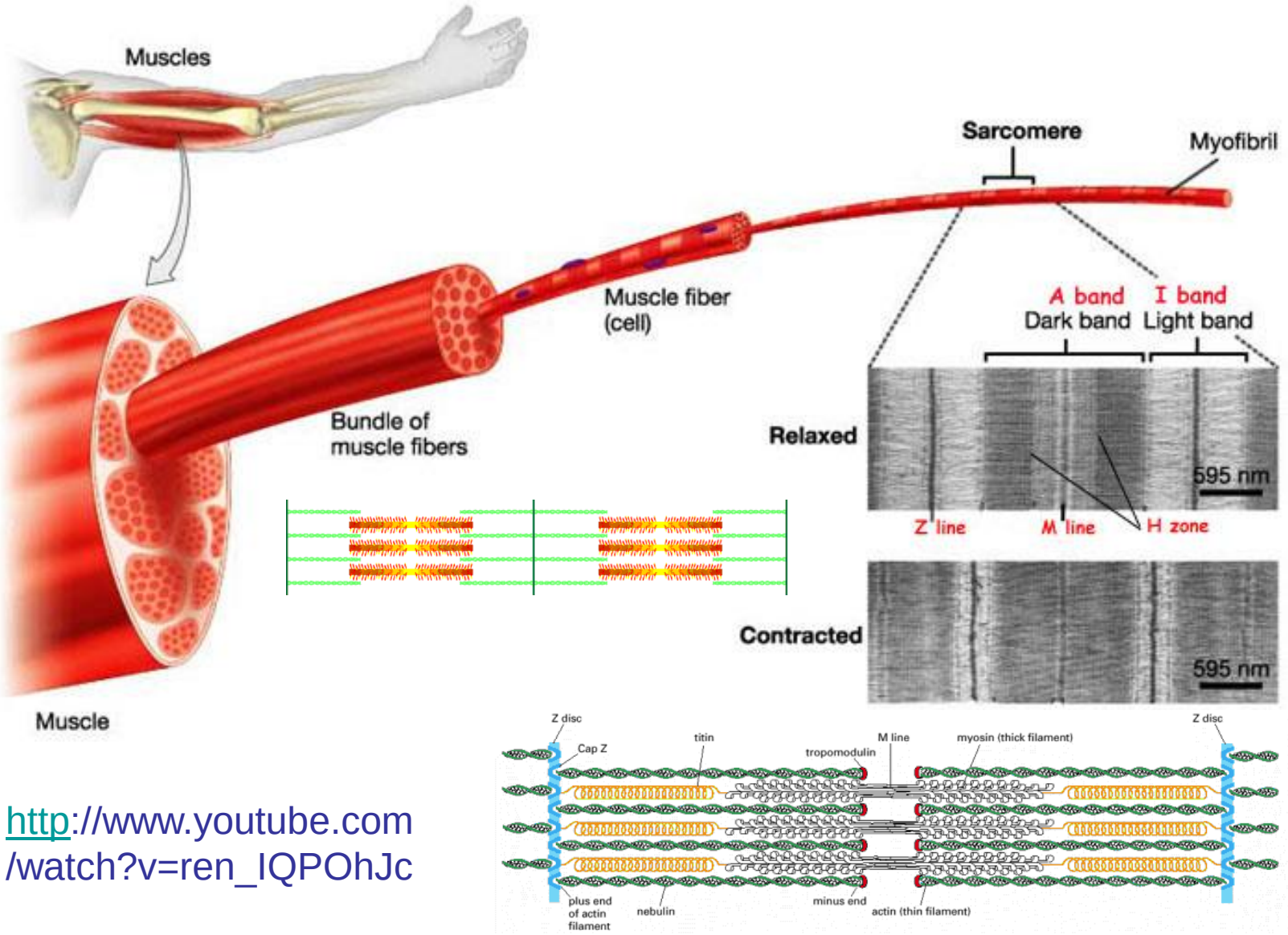
RELEASED A molecule of ATP binds to the large cleft on the "back" of the head (that is, on the side furthest from the actin filament) and immediately causes a slight change in the conformation of the domains that make up the actin-binding site. This reduces the affinity of the head for actin and allows it to move along the filament. (The space drawn here between the head and actin emphasizes this change, although in reality the head probably remains very close to the actin.)

COCKED The cleft closes like a clam shell around the ATP molecule, triggering a large shape change that causes the head to be displaced along the filament by a distance of about 5 nm. Hydrolysis of ATP occurs, but the ADP and inorganic phosphate (P_i) produced remain tightly bound to the protein.

FORCE-GENERATING A weak binding of the myosin head to a new site on the actin filament causes release of the inorganic phosphate produced by ATP hydrolysis, concomitantly with the tight binding of the head to actin. This release triggers the power stroke—the force-generating change in shape during which the head regains its original conformation. In the course of the power stroke, the head loses its bound ADP, thereby returning to the start of a new cycle.

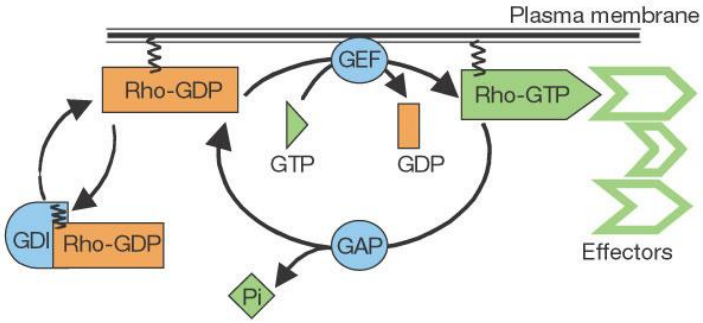
ATTACHED At the end of the cycle, the myosin head is again locked tightly to the actin filament in a rigor configuration. Note that the head has moved to a new position on the actin filament.

Sarcomeres

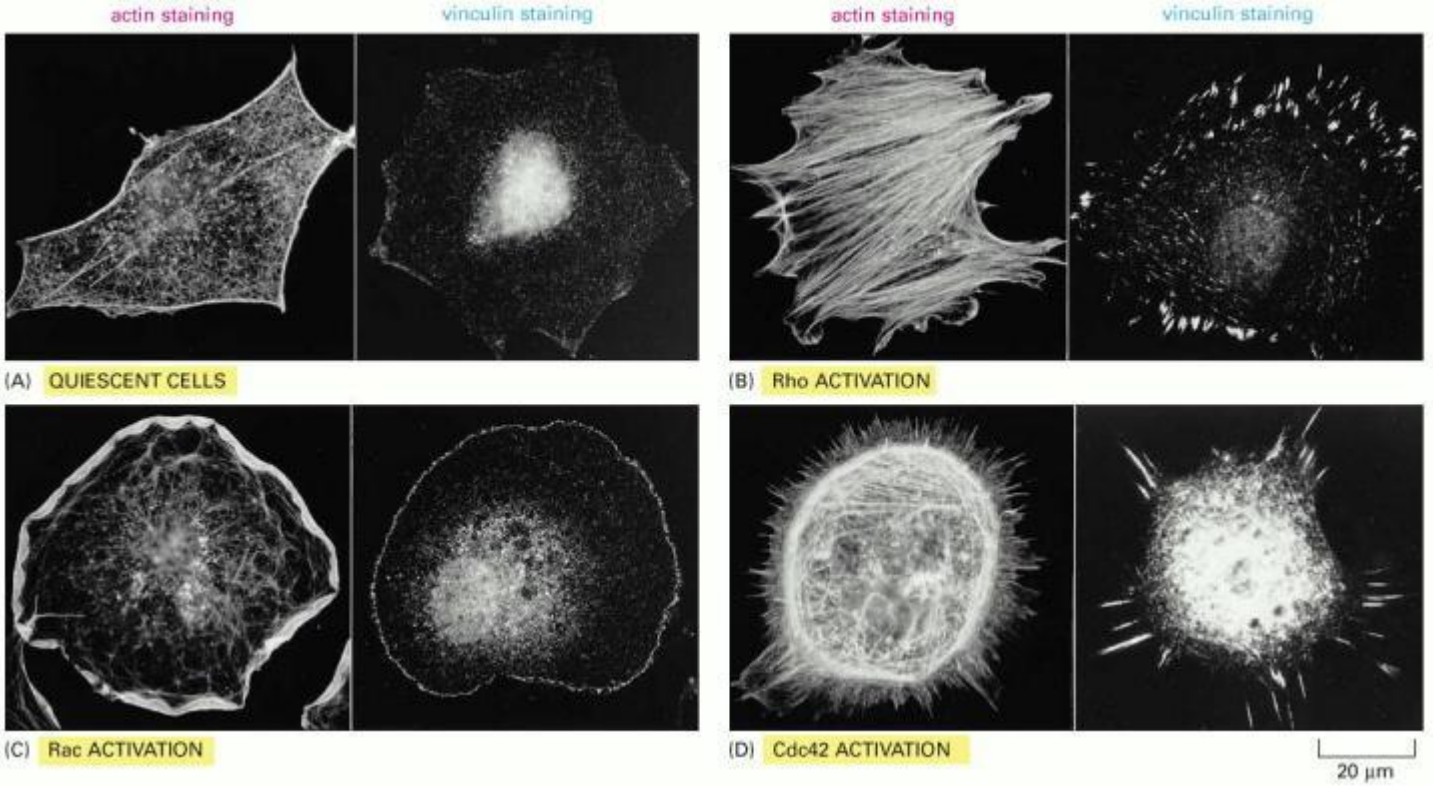


http://www.youtube.com/watch?v=ren_IQPOhJc

Rho Family GTPases

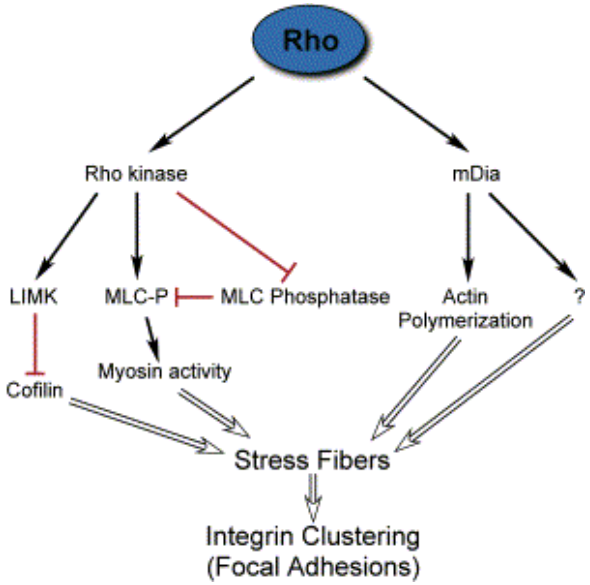


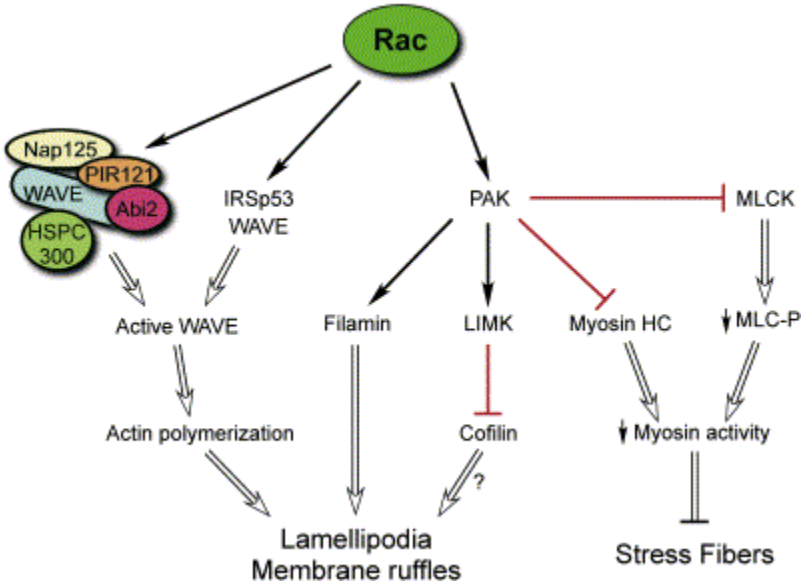
An interesting discovery by Anne Ridley and Alan Hall while studying the oncogene *ras*…

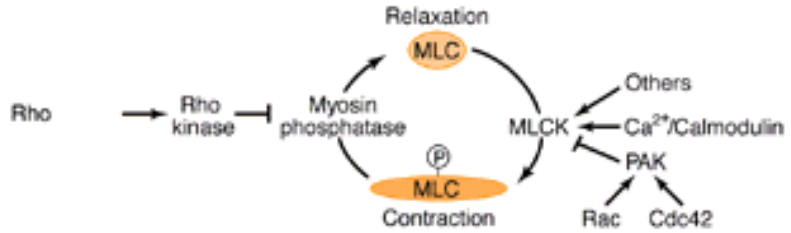


Rho and Rac Effectors

- Rho promotes CSK tension and Rac helps migration and cell elongation

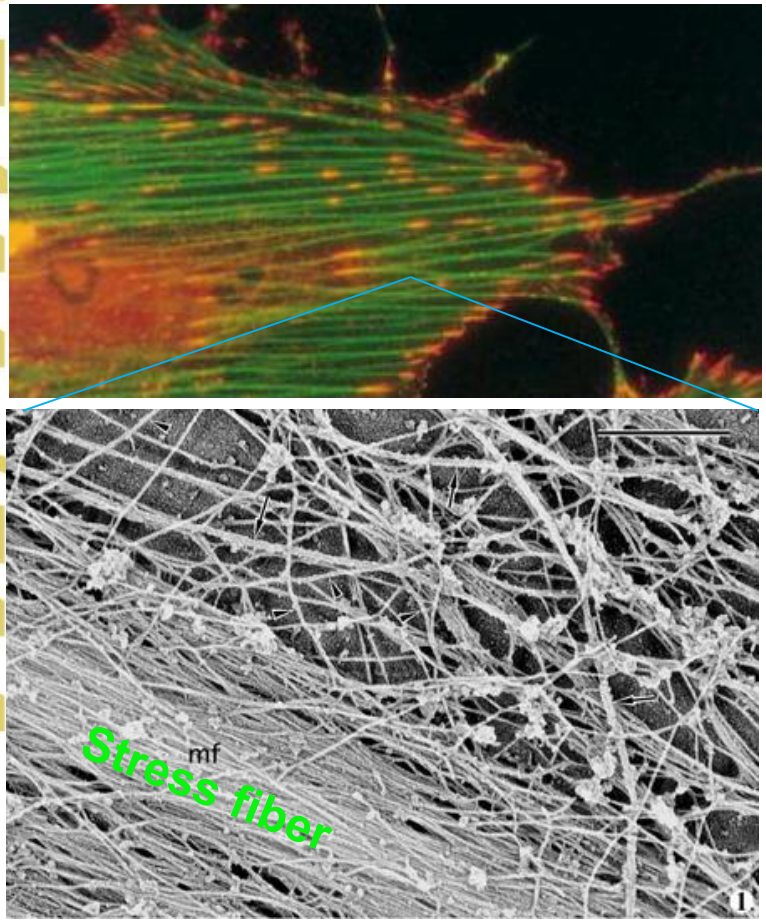


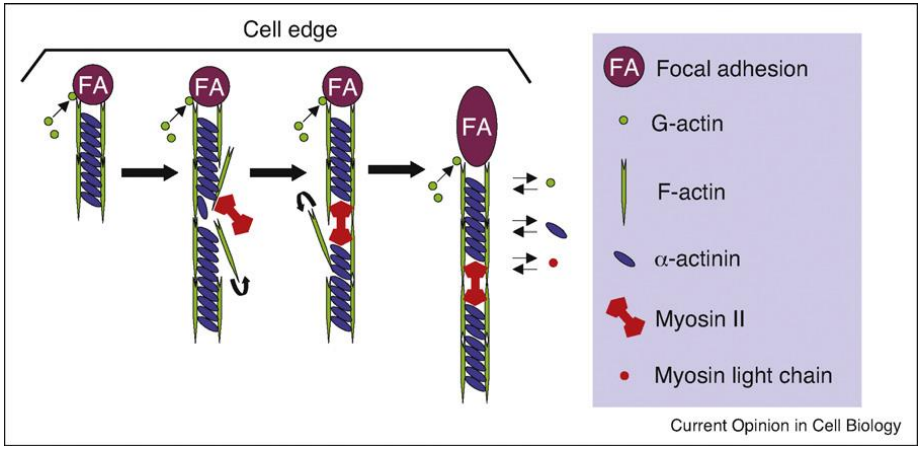


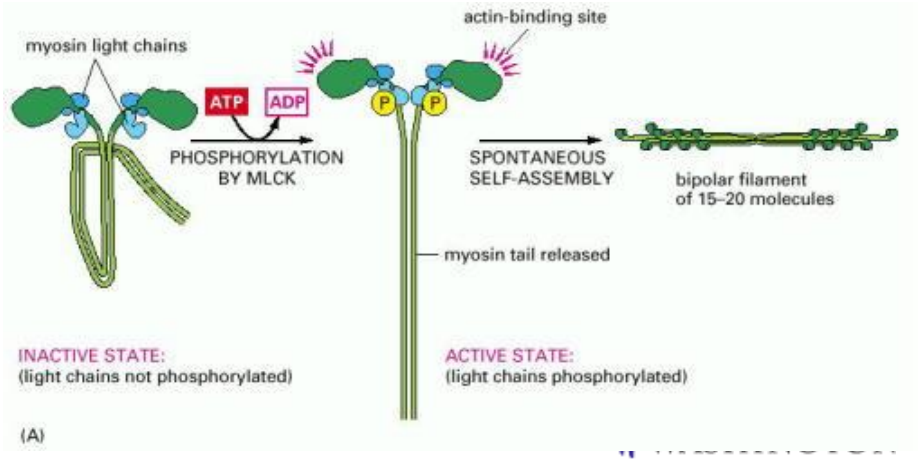


Stress Fibers

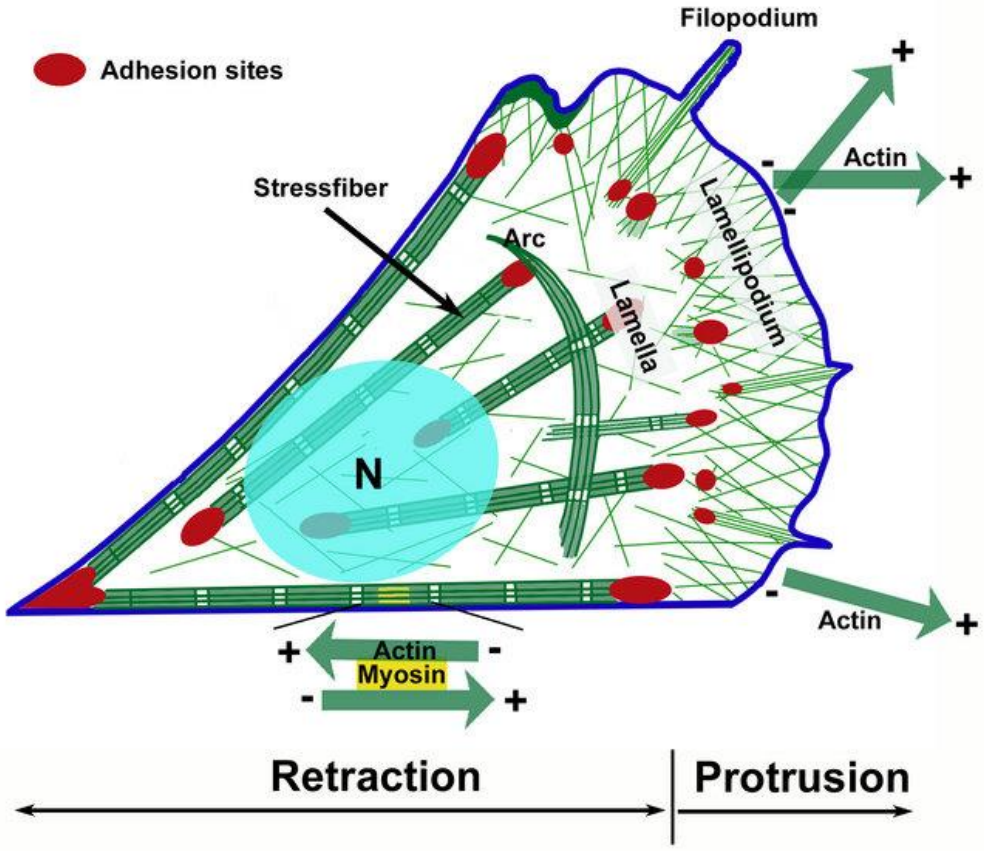
- Transient bundled structures

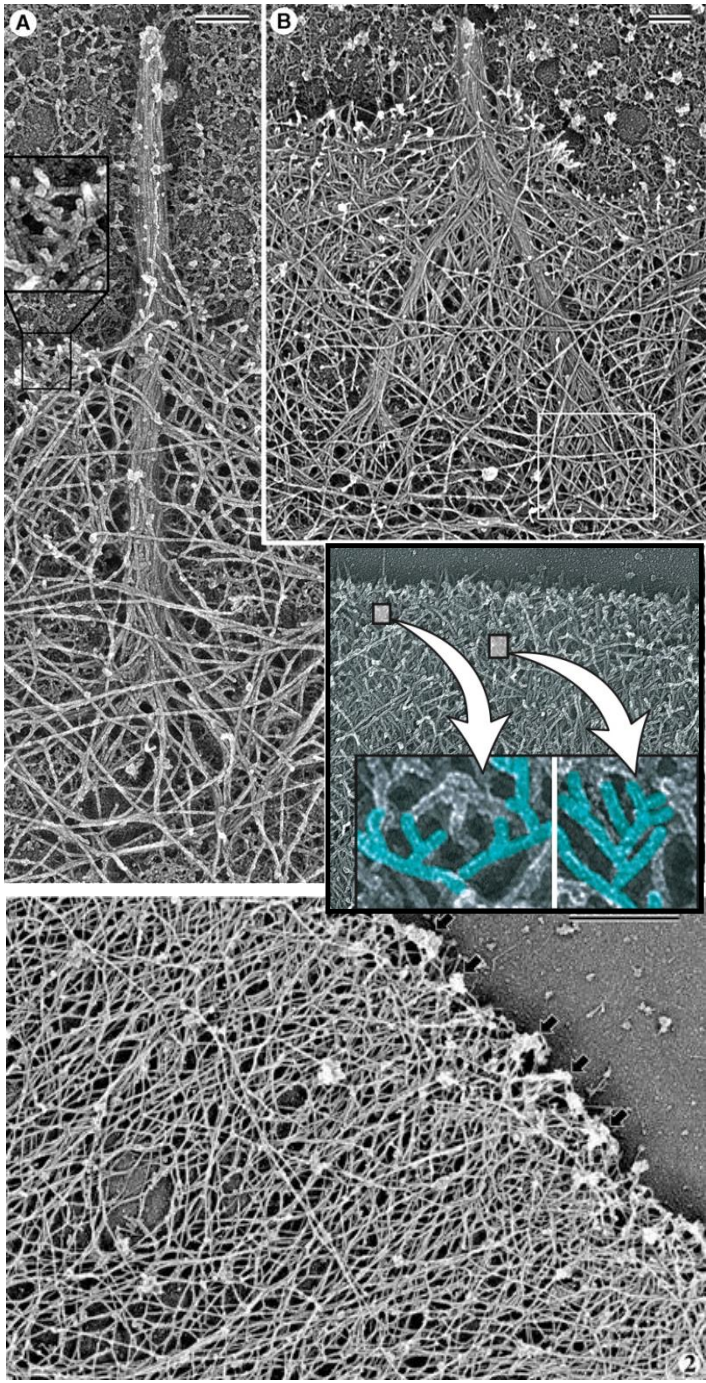






Lamellipodium & Filopodia





Questions?