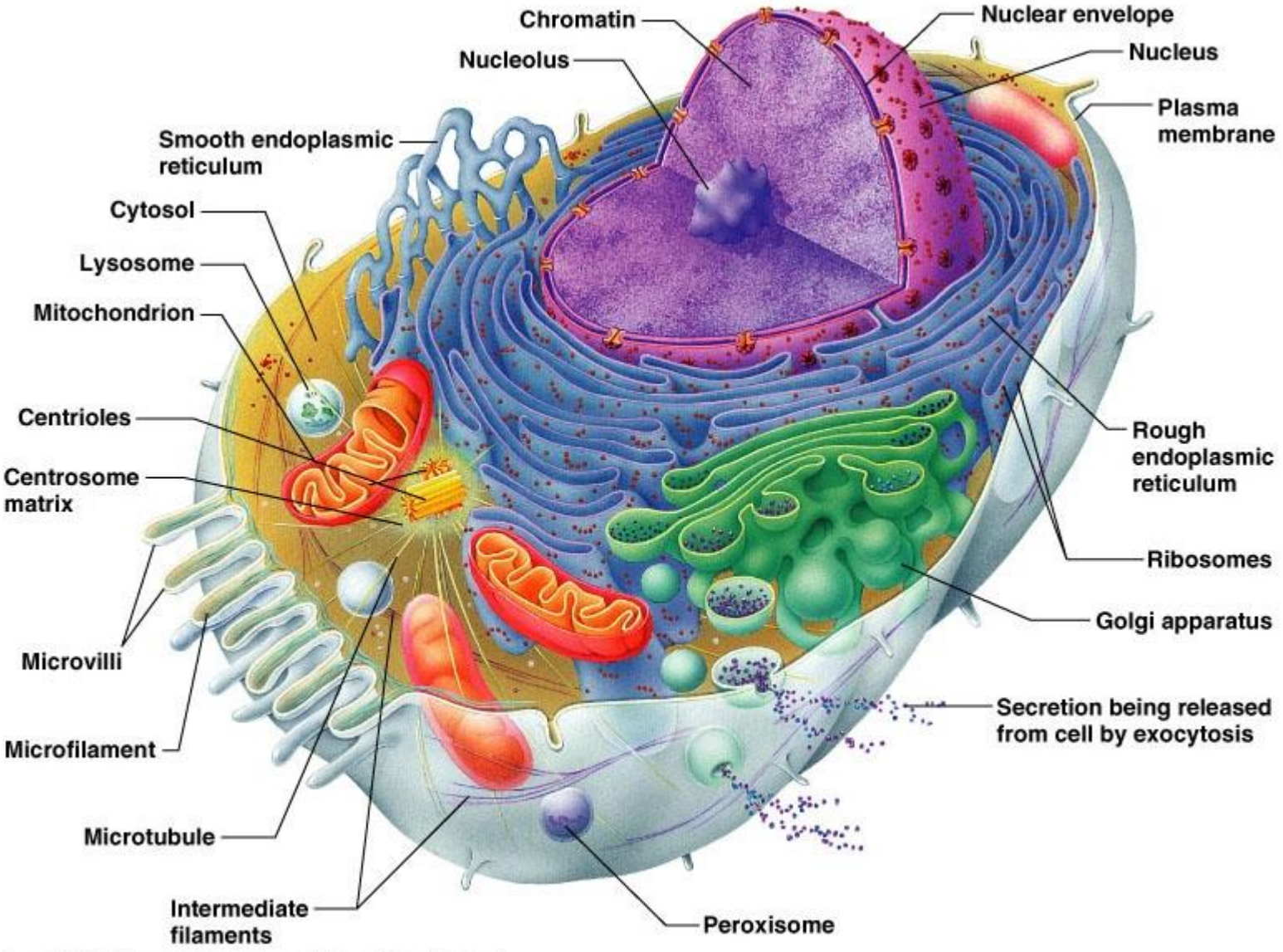
# Chemical aspects of the cell

## Shape and structure of the cell

# Cellular composition






https://www.studyblue.com/

# Cellular composition

Set of videos with basic information:

Cell characteristics: https://www.youtube.com/watch?v=URUJD5NEXC8

Golgi Complex and protein transport:
https://www.youtube.com/watch?v=rvfvRgk0MfA

Mitochondrion: https://www.youtube.com/watch?v=39HTpUG1MwQ
https://www.youtube.com/watch?v=nD9fyuisMkg

Endoplasmatic reticulum: https://www.youtube.com/watch?v=faE3STnfIGs

Lysosome: https://www.youtube.com/watch?v=ekdIEpSf-1I

# Cell cytoskeleton

Actin filaments determine the shape of the cell's surface and are necessary for whole-cell locomotion; they also drive the pinching of one cell into two. Microtubules determine the positions of membrane-enclosed organelles, direct intracellular transport, and form the mitotic spindle that segregates chromosomes during cell division. Intermediate filaments provide mechanical strength.

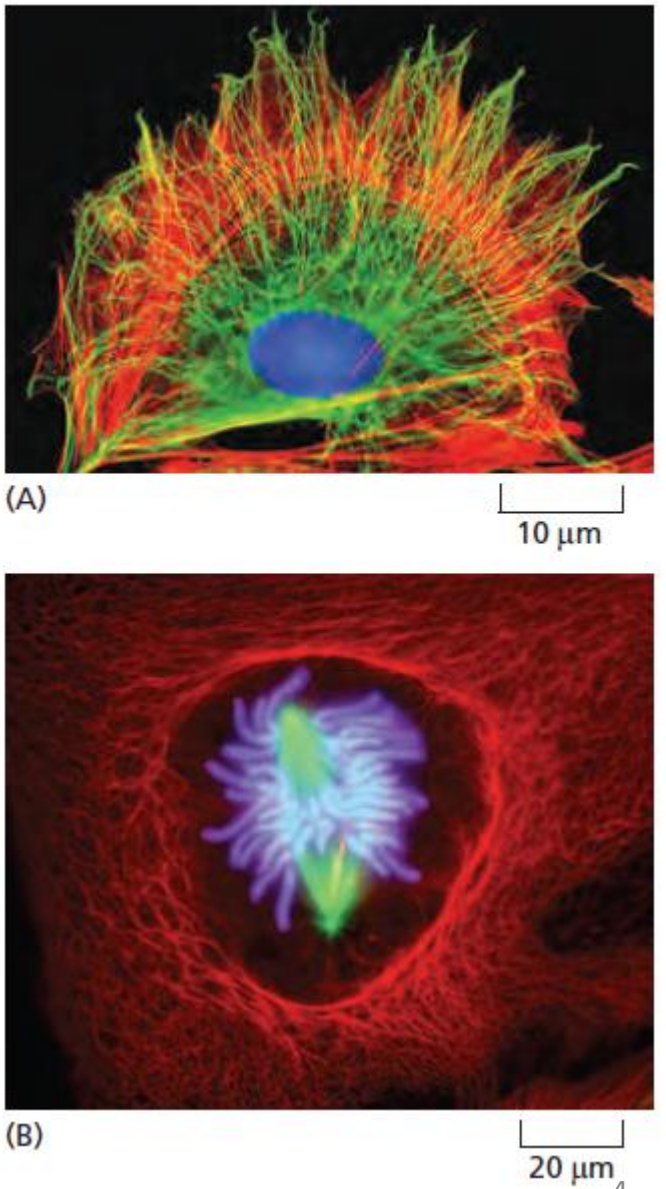
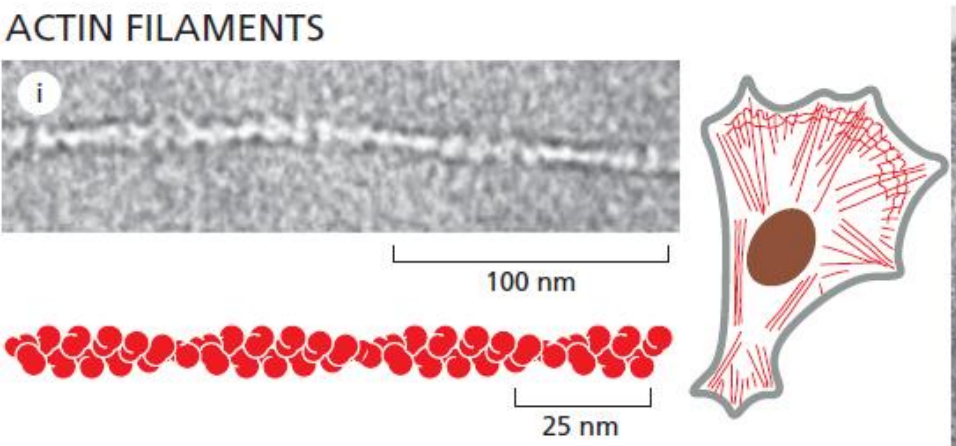


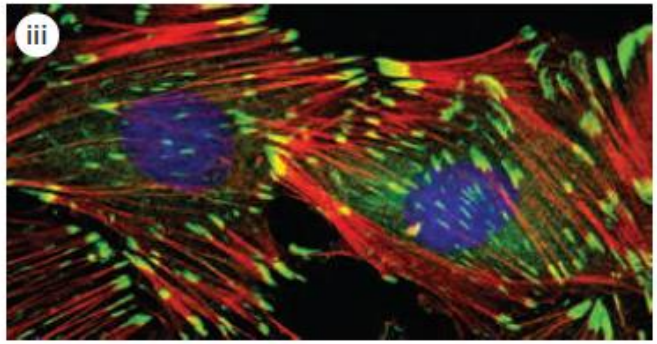

Figure 16–1 The cytoskeleton. (A) Labeled to show its cytoplasmic arrays of microtubules *(green)* and actin filaments *(red)*. (B) This dividing cell shows its spindle microtubules *(green)* and surrounding cage of intermediate filaments *(red)*. The DNA in both cells is labeled in *blue*.

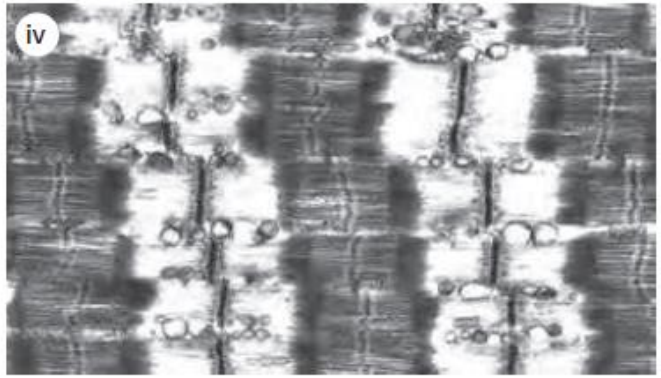
Molecular Biology of the Cell.

# Cell cytoskeleton




Actin filaments (also known as *microfilaments*) are helical polymers of the protein actin. They are flexible structures with a diameter of 8 nm that organize 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. (i) Single actin filament; (ii) microvilli; (iii) stress fibers (*red*) terminating in focal adhesions (*green*); (iv) striated muscle.

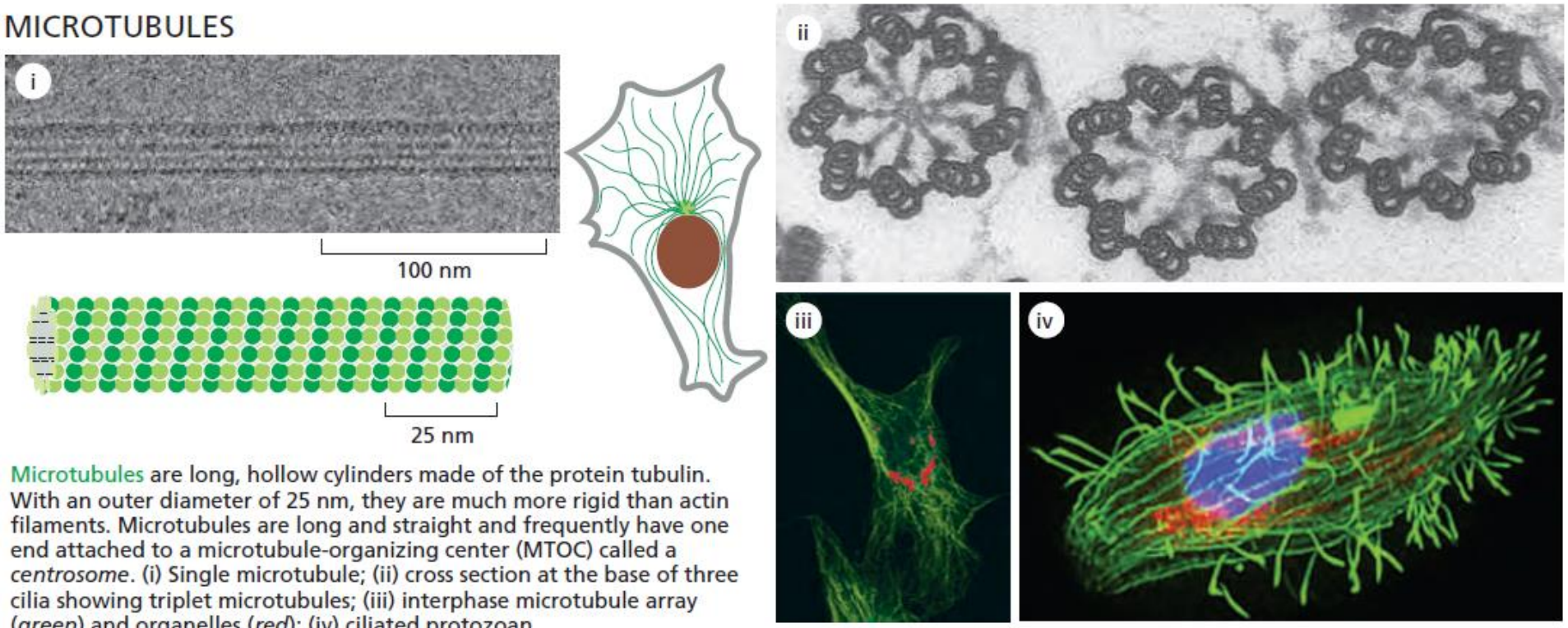




Micrographs courtesy of R. Craig (i and iv); P.T. Matsudaira and D.R. Burgess (ii); K. Burridge (iii).

Molecular Biology of the Cell.

# Cell cytoskeleton




Microtubules are long, hollow cylinders made of the protein tubulin. With an outer diameter of 25 nm, they are much more rigid than actin filaments. Microtubules are long and straight and frequently have one end attached to a microtubule-organizing center (MTOC) called a *centrosome*. (i) Single microtubule; (ii) cross section at the base of three cilia showing triplet microtubules; (iii) interphase microtubule array (*green*) and organelles (*red*); (iv) ciliated protozoan.

Micrographs courtesy of R. Wade (i); D.T. Woodrow and R.W. Linck (ii); D. Shima (iii); D. Burnette (iv).

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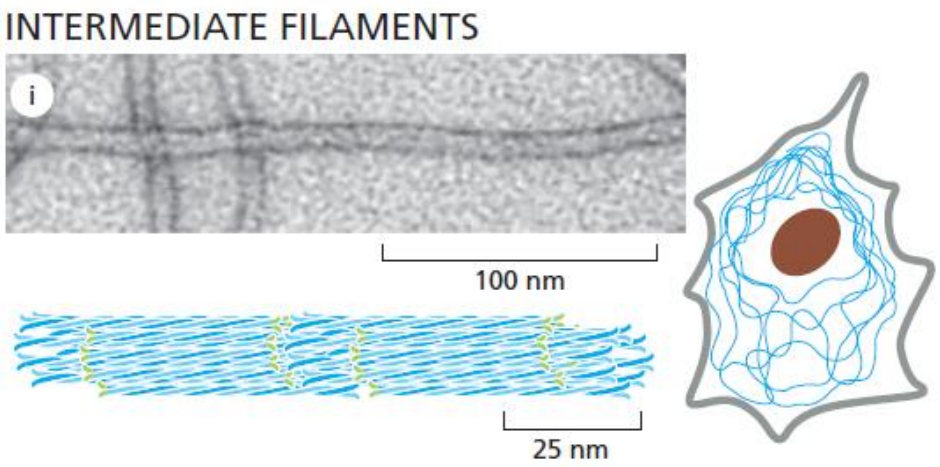
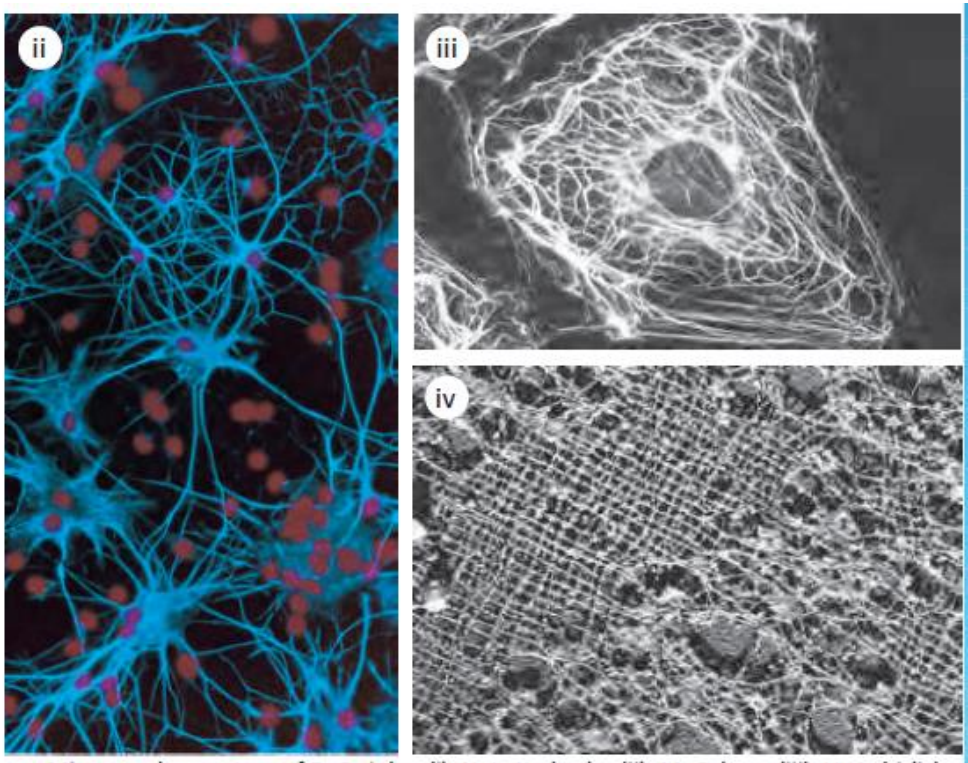
# Cell cytoskeleton




Intermediate filaments are ropelike fibers with a diameter of about 10 nm; they are made of intermediate filament proteins, which constitute a large and heterogeneous family. One type of intermediate filament forms a meshwork called the nuclear lamina just beneath the inner nuclear membrane. Other types extend across the cytoplasm, giving cells mechanical strength. In an epithelial tissue, they span the cytoplasm from one cell–cell junction to another, thereby strengthening the entire epithelium. (i) Individual intermediate filaments; (ii) Intermediate filaments (*blue*) in neurons and (iii) epithelial cell; (iv) nuclear lamina.




Micrographs courtesy of R. Quinlan (i); N. L. Kedersha (ii); M. Osborn (iii); U. Aebi (iv).

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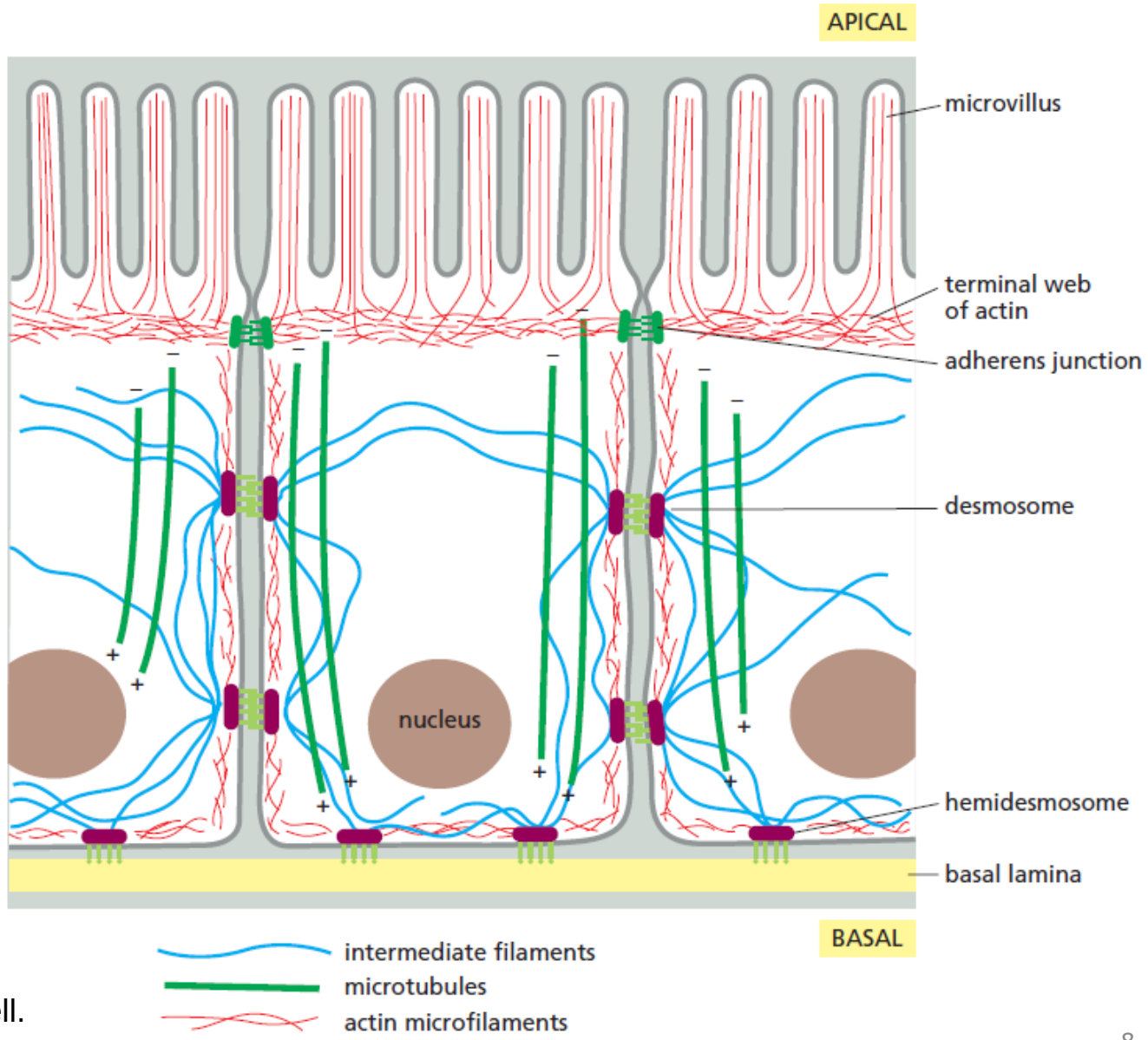
# Cell cytoskeleton

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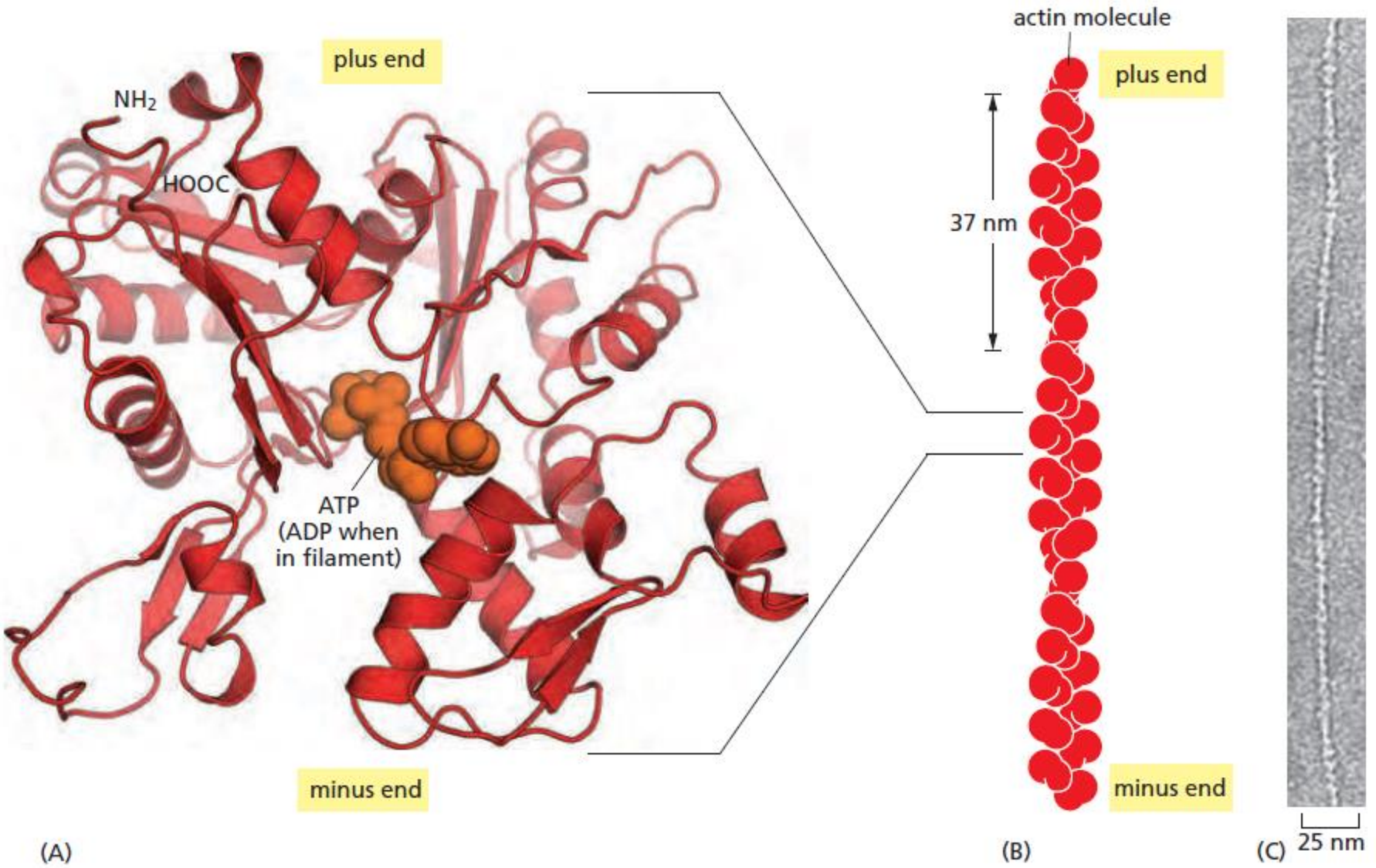
# Actin structure




Molecular Biology of the Cell.

# Actin polarity

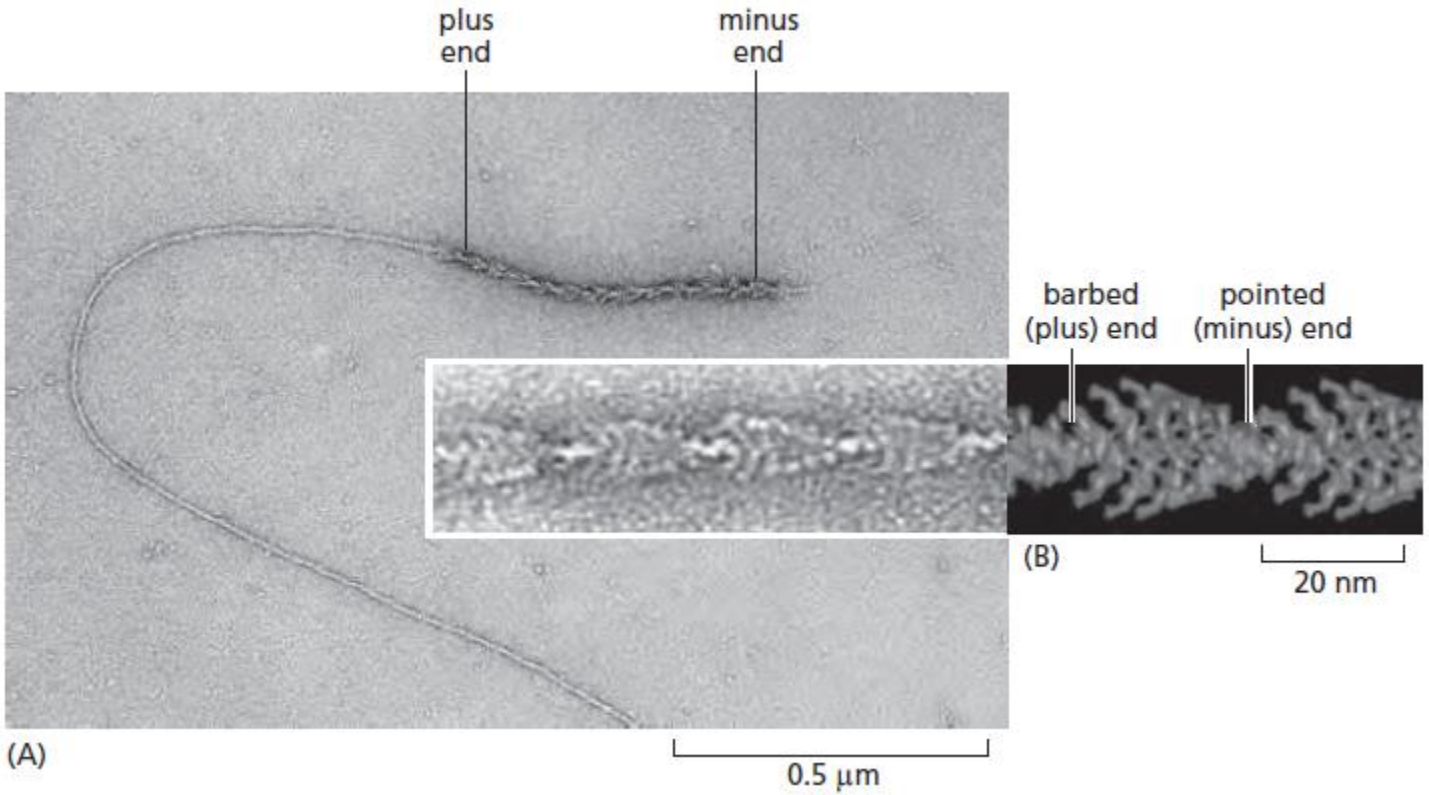



Figure 16–12 Structural polarity of the actin filament. (A) This electron micrograph shows an actin filament polymerized from a short actin filament seed that was decorated with myosin motor domains, resulting in an arrowhead pattern. The filament has grown much faster at the barbed (plus) end than at the pointed (minus) end. (B) Enlarged image and model showing the arrowhead pattern.

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# Actin polymerization

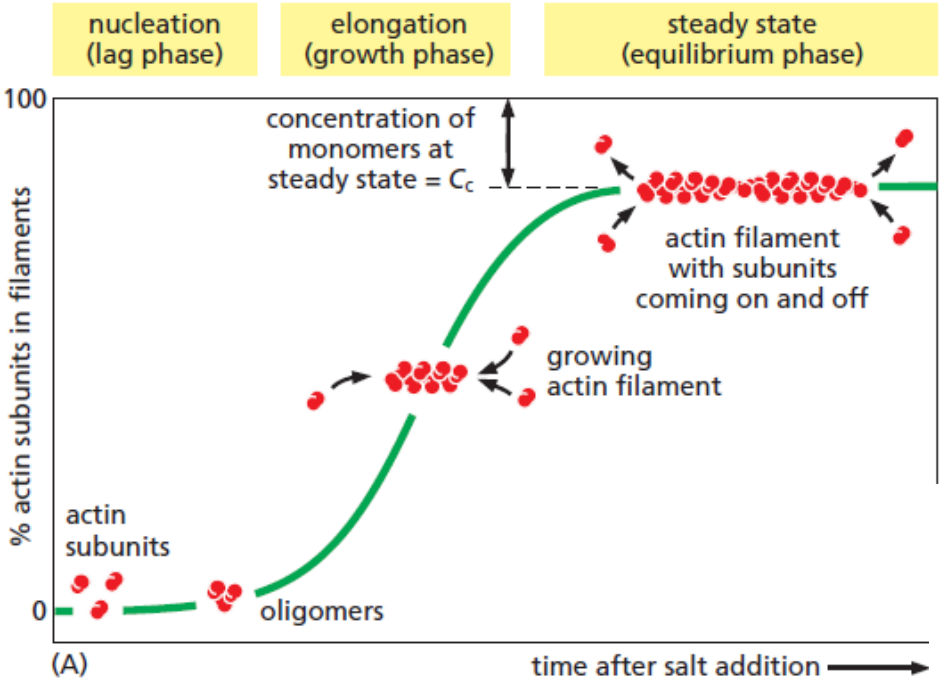
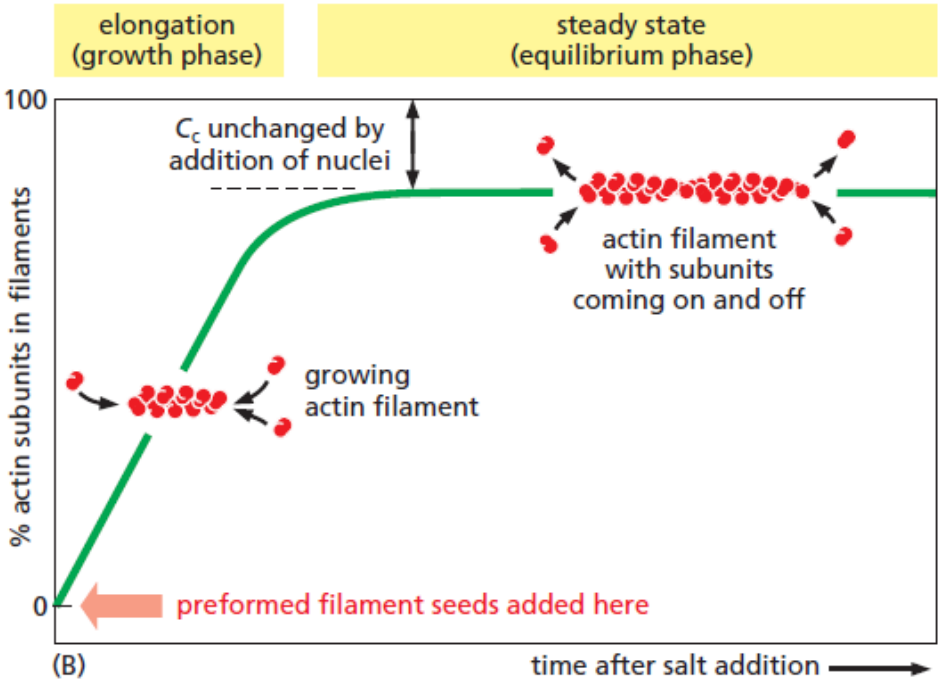
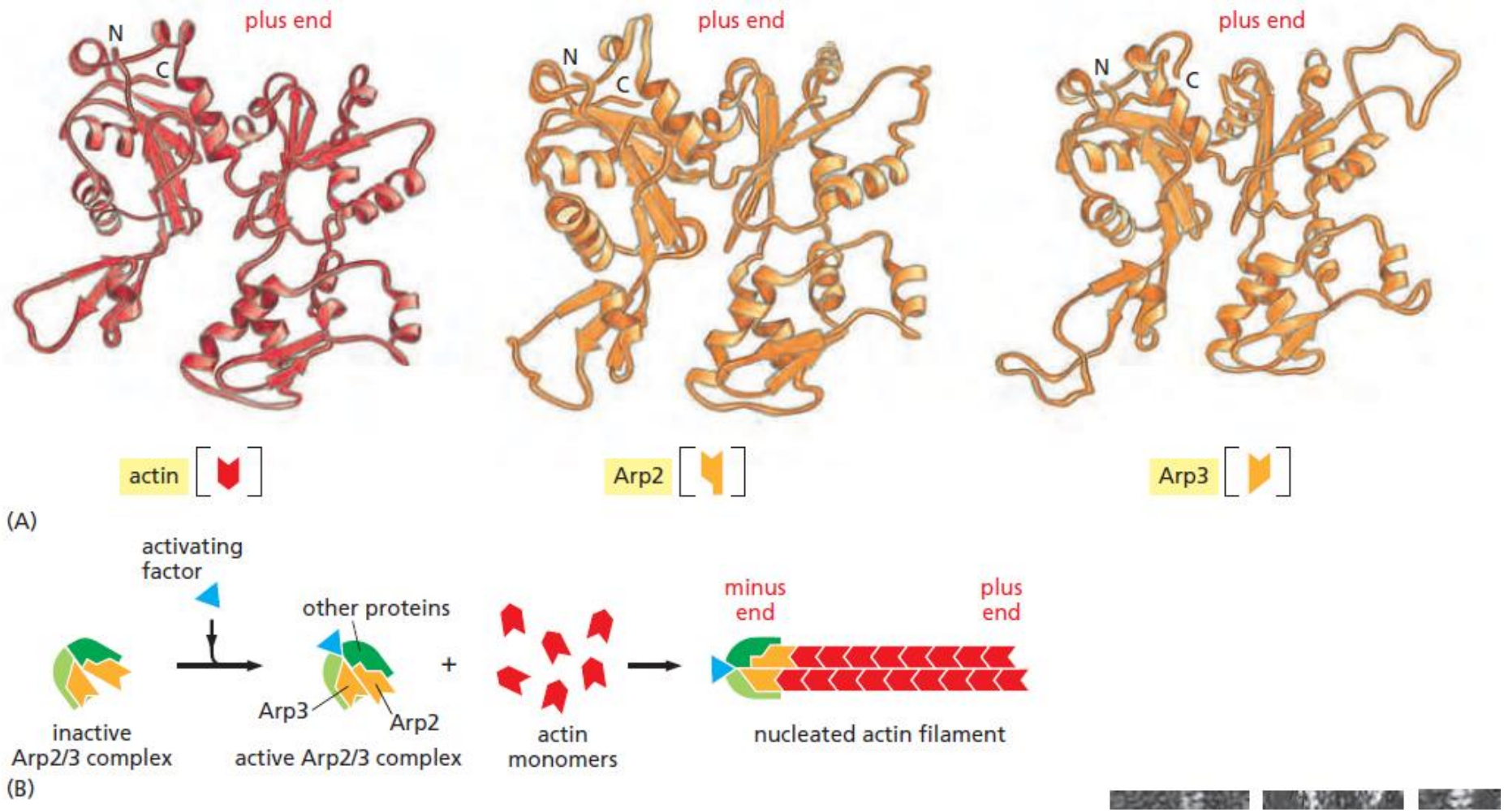



Figure 16–13 The time course of actin polymerization in a test tube. (A) Polymerization of pure actin subunits into filaments occurs after a lag phase. (B) Polymerization occurs more rapidly in the presence of preformed fragments of actin filaments, which act as nuclei for filament growth.




Molecular Biology of the Cell.

# Actin elongation by Arp proteins

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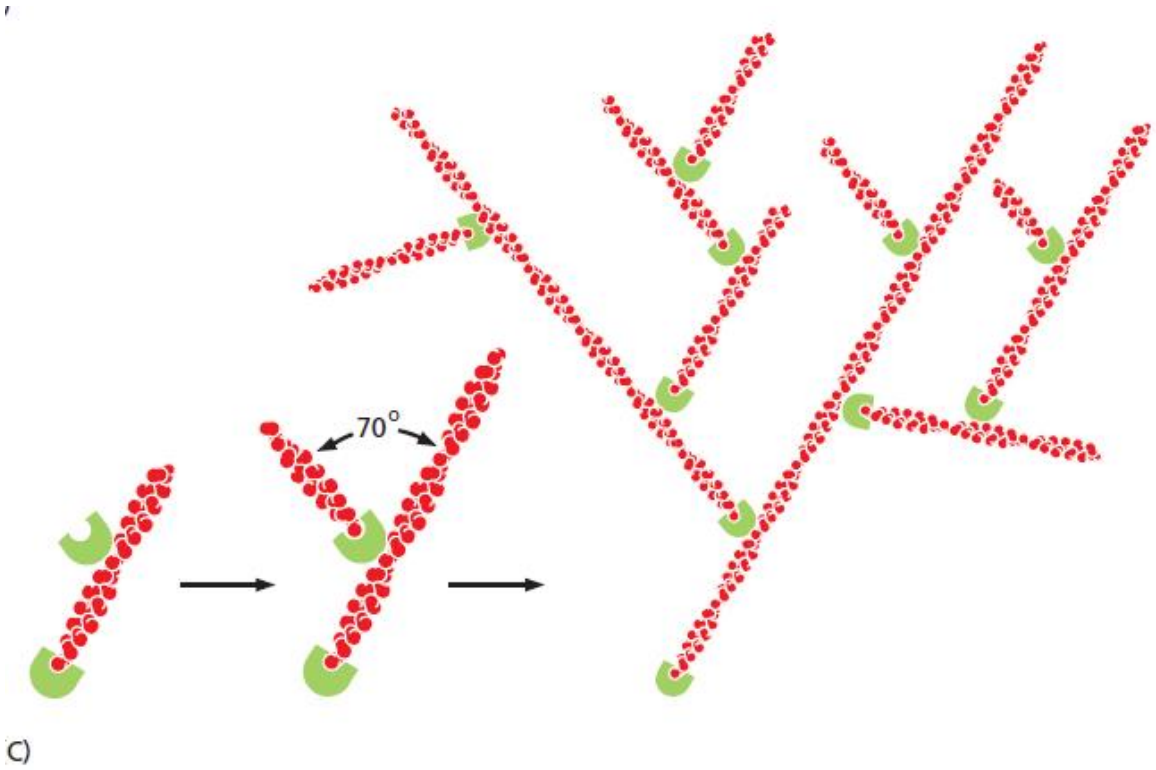
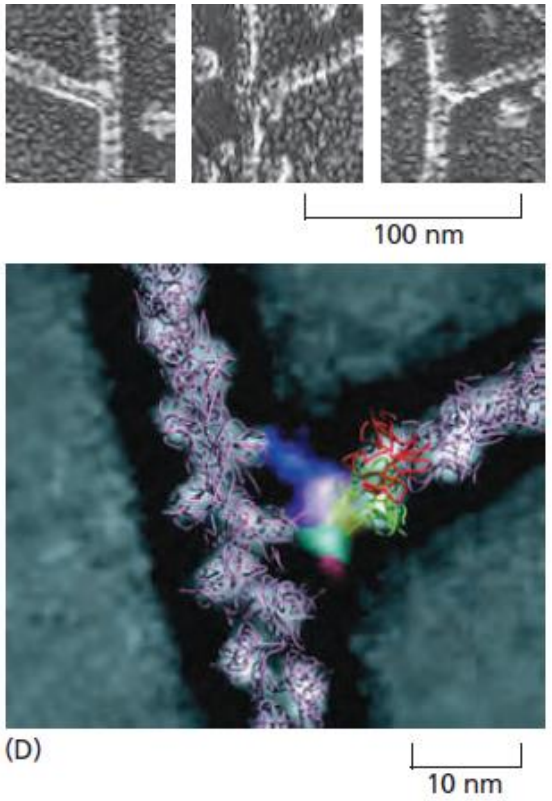
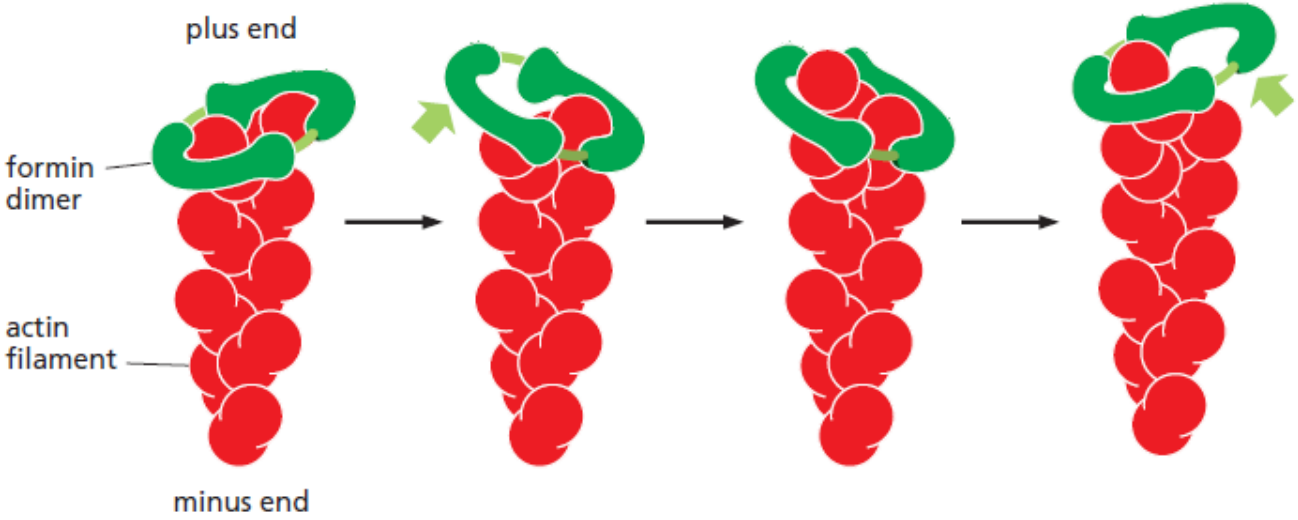
# Actin elongation by Arp proteins




Molecular Biology of the Cell.

# Actin elongation by formins and profilin



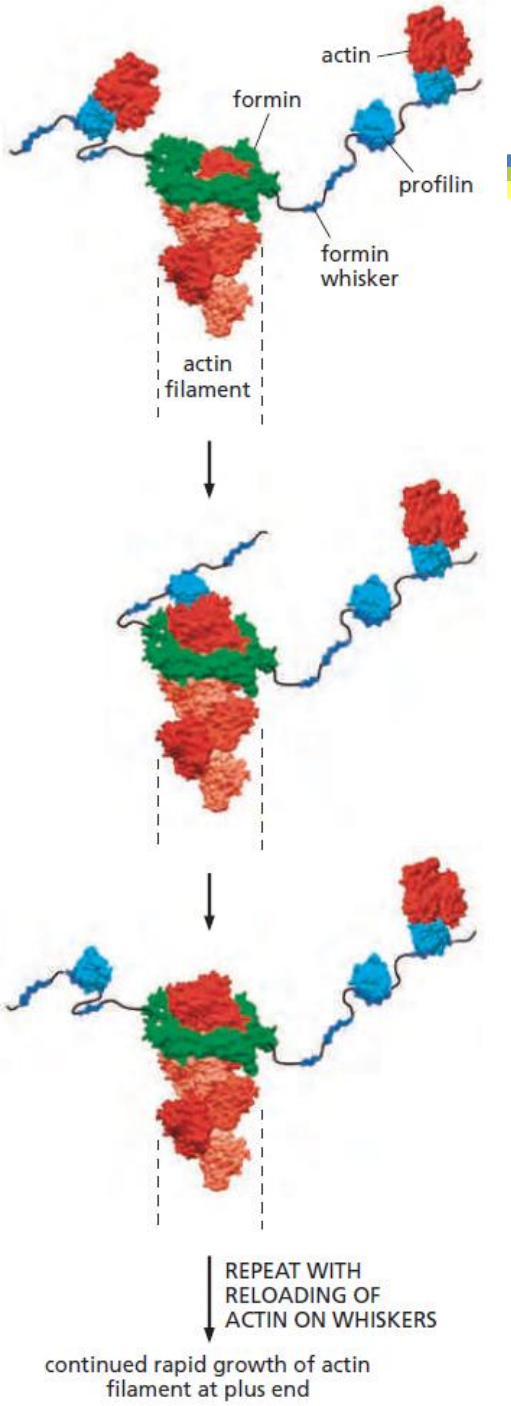




Fig. 16.17 & 16.18 - Molecular Biology of the Cell.

# Actin arrays

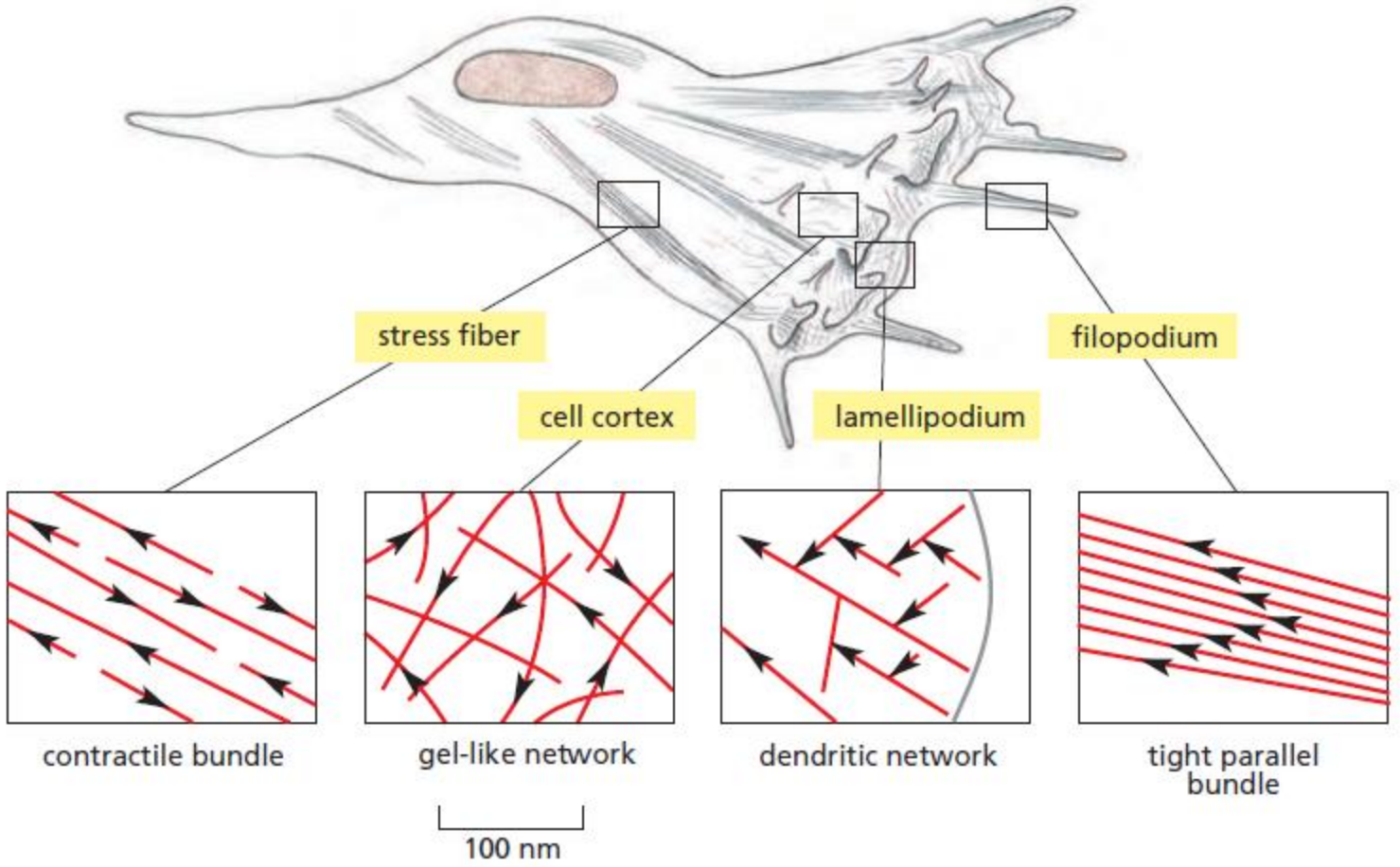



Fig. 16.21 - Molecular Biology of the Cell.

# Myosin II

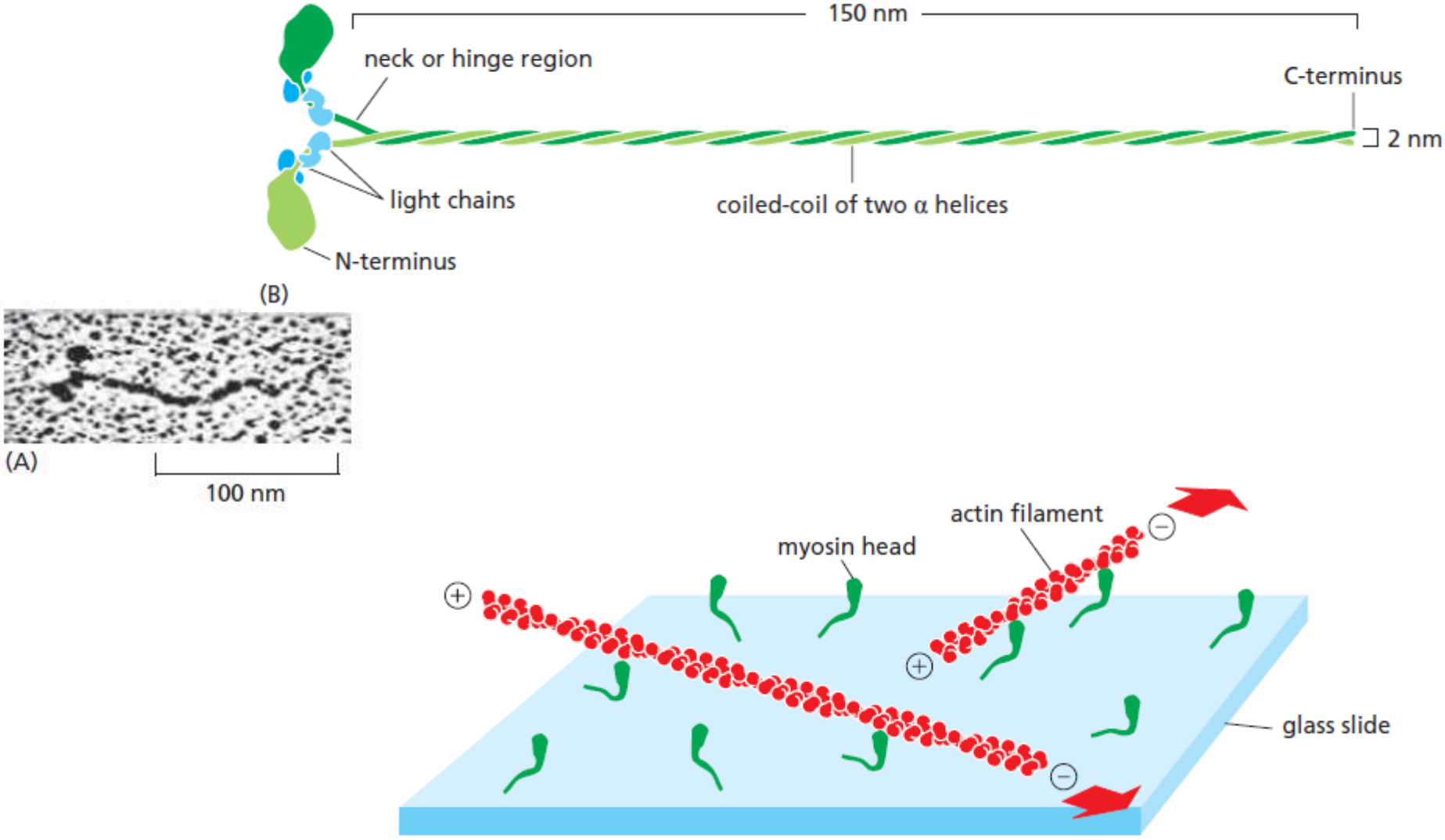



Fig. 16.26 & 16.28 - Molecular Biology of the Cell.

# Actin-Myosin movement

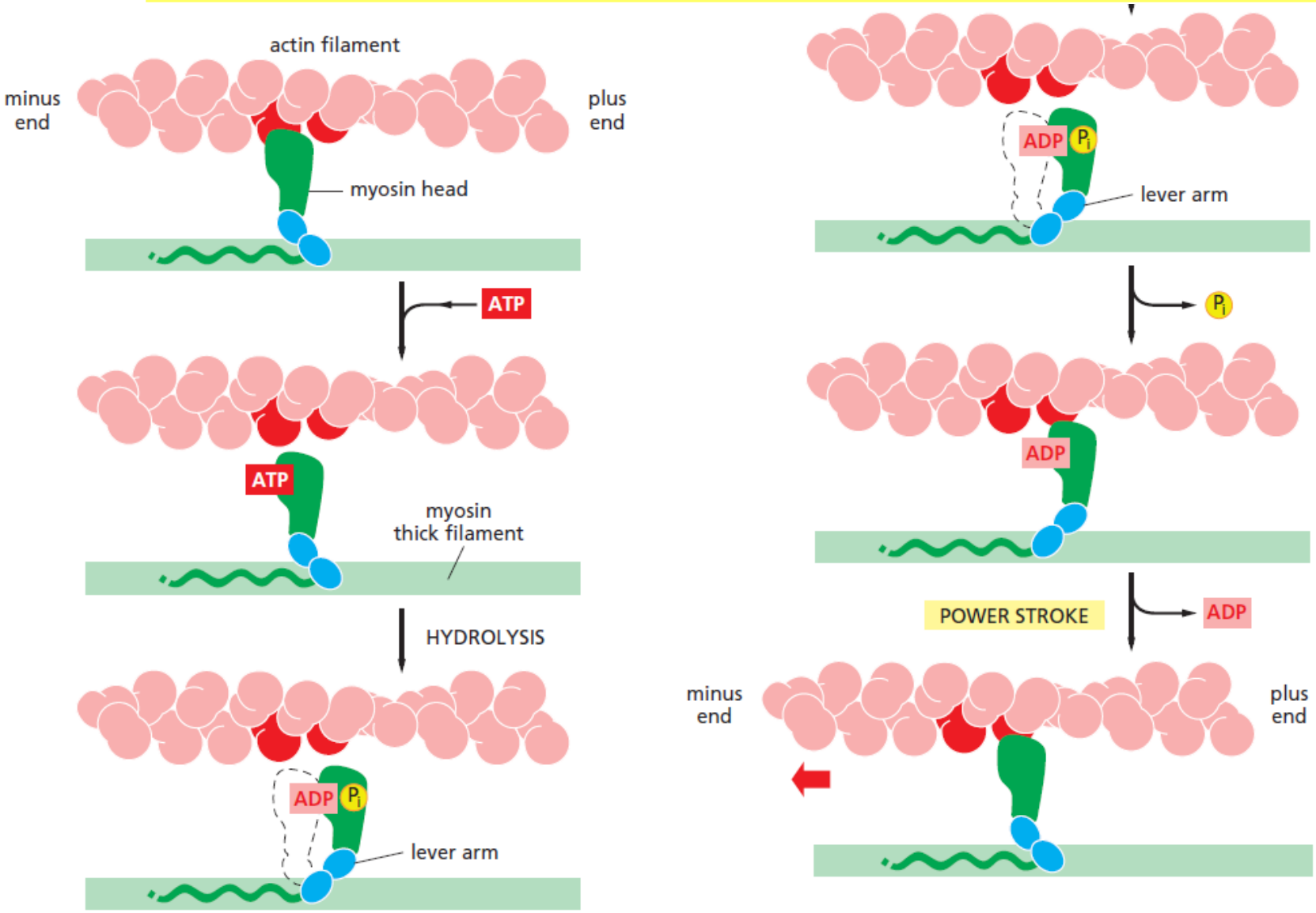



Fig. 16.29 - Molecular Biology of the Cell.

# Tubulin structure

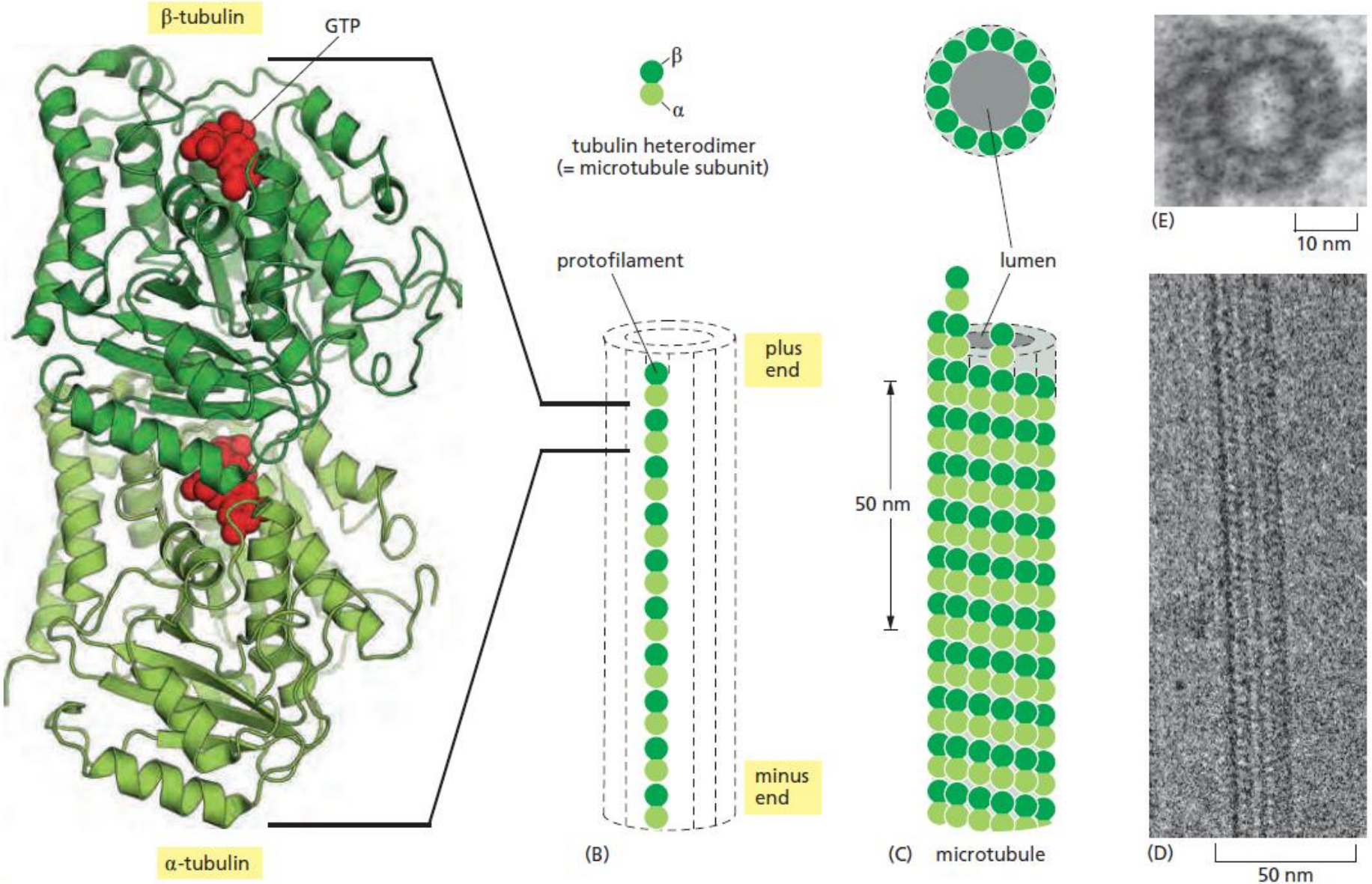



Fig. 16.42 - Molecular Biology of the Cell.

# Most common types of intermediate filaments

| TABLE 16–2 Major Types of Intermediate Filament Proteins in Vertebrate Cells | | |
|---|---|---|
| Types of intermediate filament | Component polypeptides | Location |
| Nuclear | Lamins A, B, and C | Nuclear lamina (inner lining of nuclear envelope) |
| Vimentin-like | Vimentin | Many cells of mesenchymal origin |
| | Desmin | Muscle |
| | Glial fibrillary acidic protein | Glial cells (astrocytes and some Schwann cells) |
| | Peripherin | Some neurons |
| Epithelial | Type I keratins (acidic) | Epithelial cells and their derivatives (e.g., hair and nails) |
| | Type II keratins (neutral/basic) | |
| Axonal | Neurofilament proteins (NF-L, NF-M, and NF-H) | Neurons |

Molecular Biology of the Cell.

# Cell junctions & cytoskeleton

Due to its close association with the cytoplasmic surface of the plasma membrane, the membrane - skeleton meshwork directly influences the functions of the plasma membrane. As a consequence of the membrane – skeleton meshwork, the plasma membrane is effectively partitioned into mesoscale domains, or compartments, with sizes varying between 30 and 250 nm.

In the plasma membrane, there are three types of major mesoscale domains ( *meso* domains):

(1) membrane compartments delineated by the actin-based membrane skeleton;
(2) raft domains, where specific proteins, glycosphingolipids, and cholesterol are concentrated;
(3) the protein oligomer domains.

*Cellular Domains*, First Edition. Edited by Ivan R. Nabi.

# Cell junctions

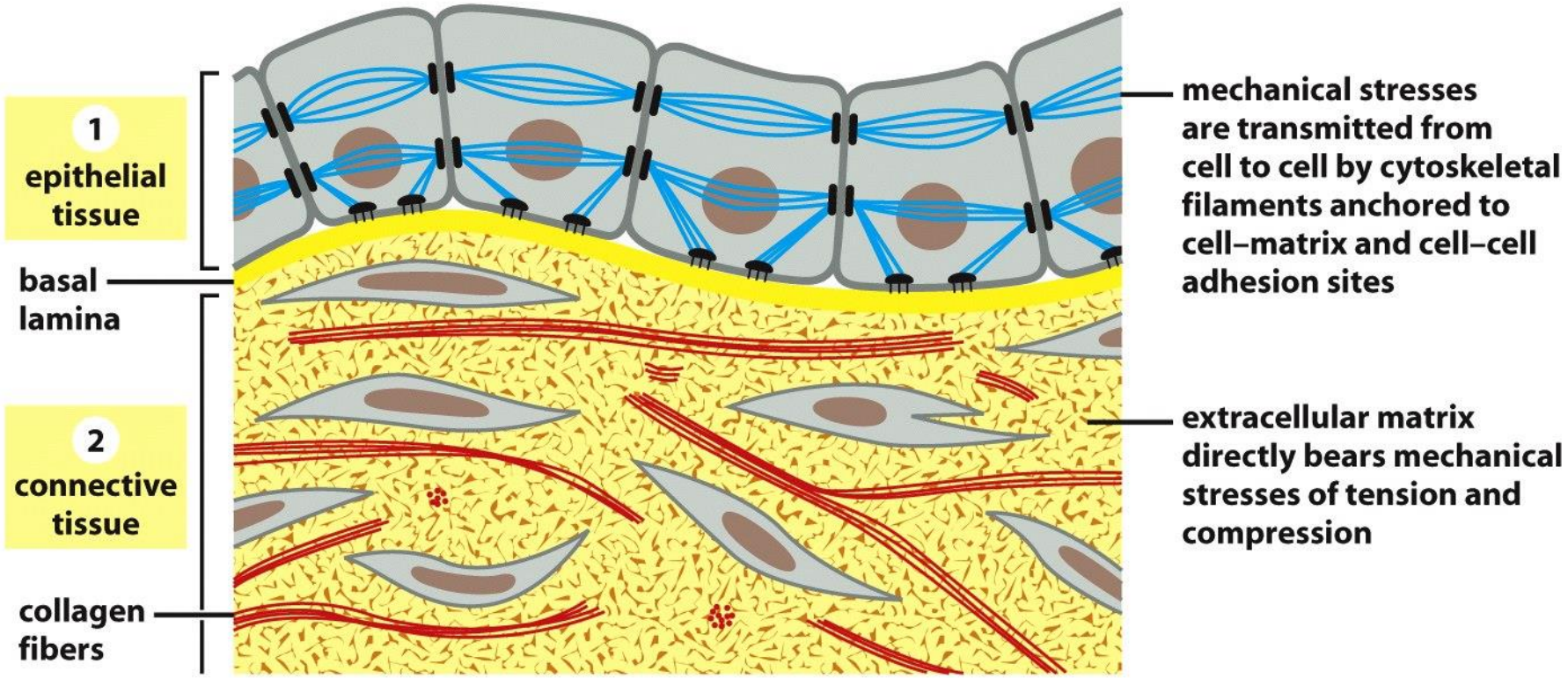
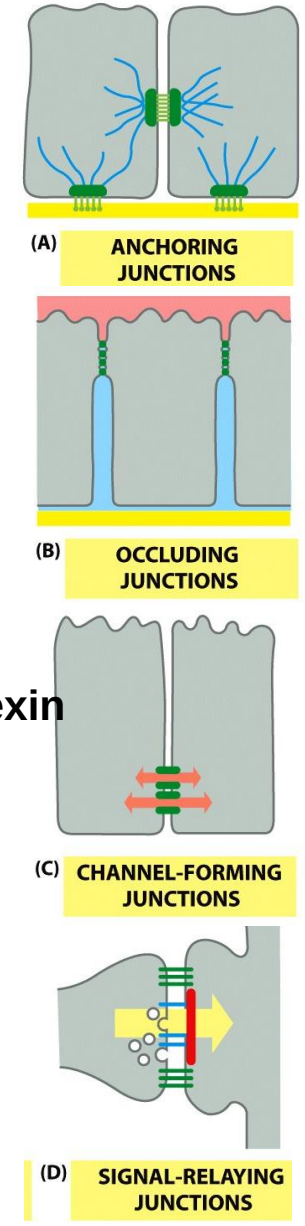



Figure 19-1 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Classification of cell junctions

**Table 19–1 A Functional Classification of Cell Junctions**

| | |
|---|---|
| **ANCHORING JUNCTIONS** | Usually cadherin and integrin |
| *Actin filament attachment sites* | |
| 1. | cell–cell junctions (adherens junctions) |
| 2. | cell–matrix junctions (actin-linked cell–matrix adhesions) |
| *Intermediate filament attachment sites* | |
| 1. | cell–cell junctions (desmosomes) |
| 2. | cell–matrix junctions (hemidesmosomes) |
| **OCCLUDING JUNCTIONS** | Involves claudin |
| 1. | tight junctions (in vertebrates) |
| 2. | septate junctions (in invertebrates) |
| **CHANNEL-FORMING JUNCTIONS** | Composed by connexin and innexin |
| 1. | gap junctions (in animals) |
| 2. | plasmodesmata (in plants) |
| **SIGNAL-RELAYING JUNCTIONS** | |
| 1. | chemical synapses (in the nervous system) |
| 2. | immunological synapses (in the immune system) |
| 3. | transmembrane ligand–receptor cell–cell signaling contacts (Delta-Notch, ephrin-Eph, etc.). Anchoring, occluding, and channel-forming junctions can all have signaling functions in addition to their structural roles |



# Classification of anchoring junctions

**Table 19–2 Anchoring Junctions**

| JUNCTION | TRANSMEMBRANE ADHESION PROTEIN | EXTRACELLULAR LIGAND | INTRACELLULAR CYTOSKELETAL ATTACHMENT | INTRACELLULAR ANCHOR PROTEINS |
|---|---|---|---|---|
| ***Cell–Cell*** | | | | |
| adherens junction | cadherin (classical cadherin) | cadherin in neighboring cell | actin filaments | α-catenin, β-catenin, plakoglobin (γ-catenin), p120-catenin, vinculin, α-actinin |
| desmosome | cadherin (desmoglein, desmocollin) | desmoglein and desmocollin in neighboring cell | intermediate filaments | plakoglobin (γ-catenin), plakophilin, desmoplakin |
| ***Cell–Matrix*** | | | | |
| actin-linked cell–matrix adhesion | integrin | extracellular matrix proteins | actin filaments | talin, vinculin, α-actinin, filamin, paxillin, focal adhesion kinase (FAK) |
| hemidesmosome | integrin α6β4, type XVII collagen (BP180) | extracellular matrix proteins | intermediate filaments | plectin, dystonin (BP230) |

Table 19-2 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Classification of cadherins

Cadherins are present in animals.

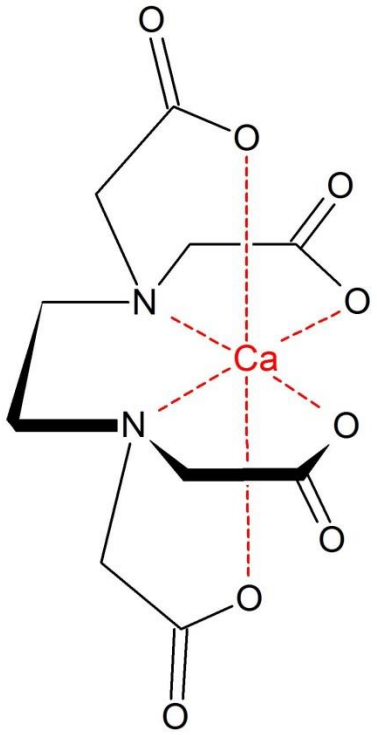
They depend on $Ca^{2+}$.

EDTA forms a complex with calcium ions.

Trypsin cleaves the extracellular part of this prote

There are more than 180 cadherins described in humans.

Important cell-cell anchoring point.



# Cadherin types

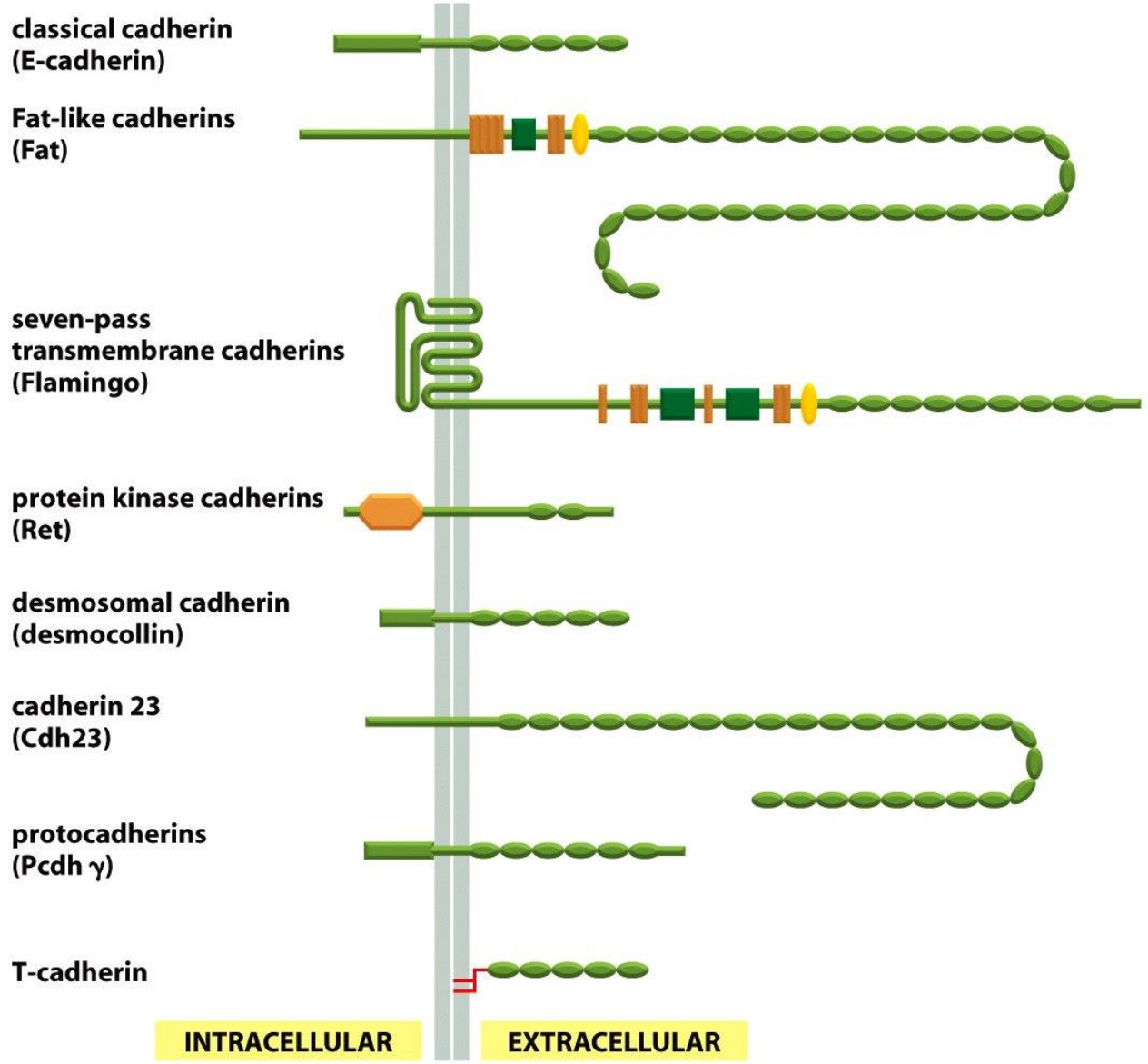



Figure 19-7 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Classification of cadherins

**Table 19–3 Some Members of the Cadherin Superfamily**

| NAME | MAIN LOCATION | JUNCTION ASSOCIATION | PHENOTYPE WHEN INACTIVATED IN MICE |
|---|---|---|---|
| ***Classical cadherins*** | | | |
| E-cadherin | many epithelia | adherens junctions | death at blastocyst stage; embryos fail to undergo compaction |
| N-cadherin | neurons, heart, skeletal muscle, lens, and fibroblasts | adherens junctions and chemical synapses | embryos die from heart defects |
| P-cadherin | placenta, epidermis, breast epithelium | adherens junctions | abnormal mammary gland development |
| VE-cadherin | endothelial cells | adherens junctions | abnormal vascular development (apoptosis of endothelial cells) |
| ***Nonclassical cadherins*** | | | |
| Desmocollin | skin | desmosomes | blistering of skin |
| Desmoglein | skin | desmosomes | blistering skin disease due to loss of keratinocyte cell–cell adhesion |
| T-cadherin | neurons, muscle, heart | none | unknown |
| Cadherin 23 | inner ear, other epithelia | links between stereocilia in sensory hair cells | deafness |
| Fat (in *Drosophila*) | epithelia and central nervous system | signal-relaying junction (planar cell polarity) | enlarged imaginal discs and tumors; disrupted planar cell polarity |
| Fat1 (in mammals) | various epithelia and central nervous system | slit diaphragm in kidney glomerulus and other cell junctions | loss of slit diaphragm; malformation of forebrain and eye |
| α, β, and γ-Protocadherins | neurons | chemical synapses and nonsynaptic membranes | neuronal degeneration |
| Flamingo | sensory and some other epithelia | cell–cell junctions | disrupted planar cell polarity; neural tube defects |

# Cadherin-cadherin interactions

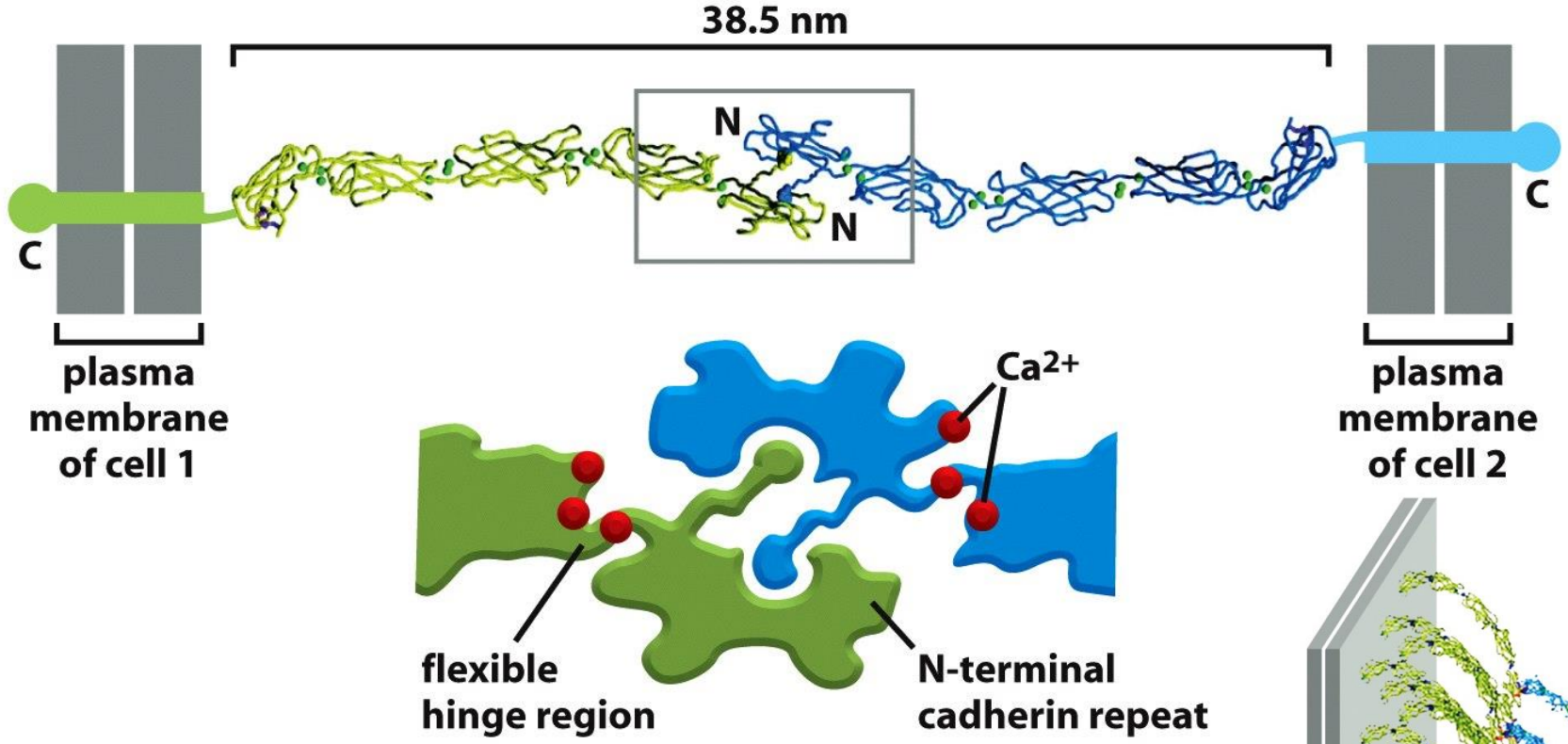
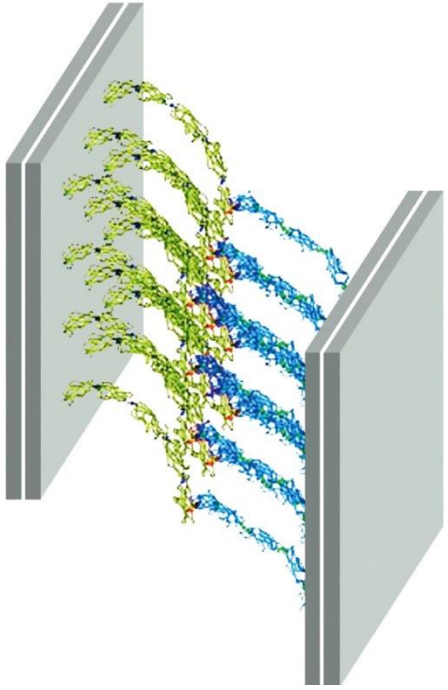
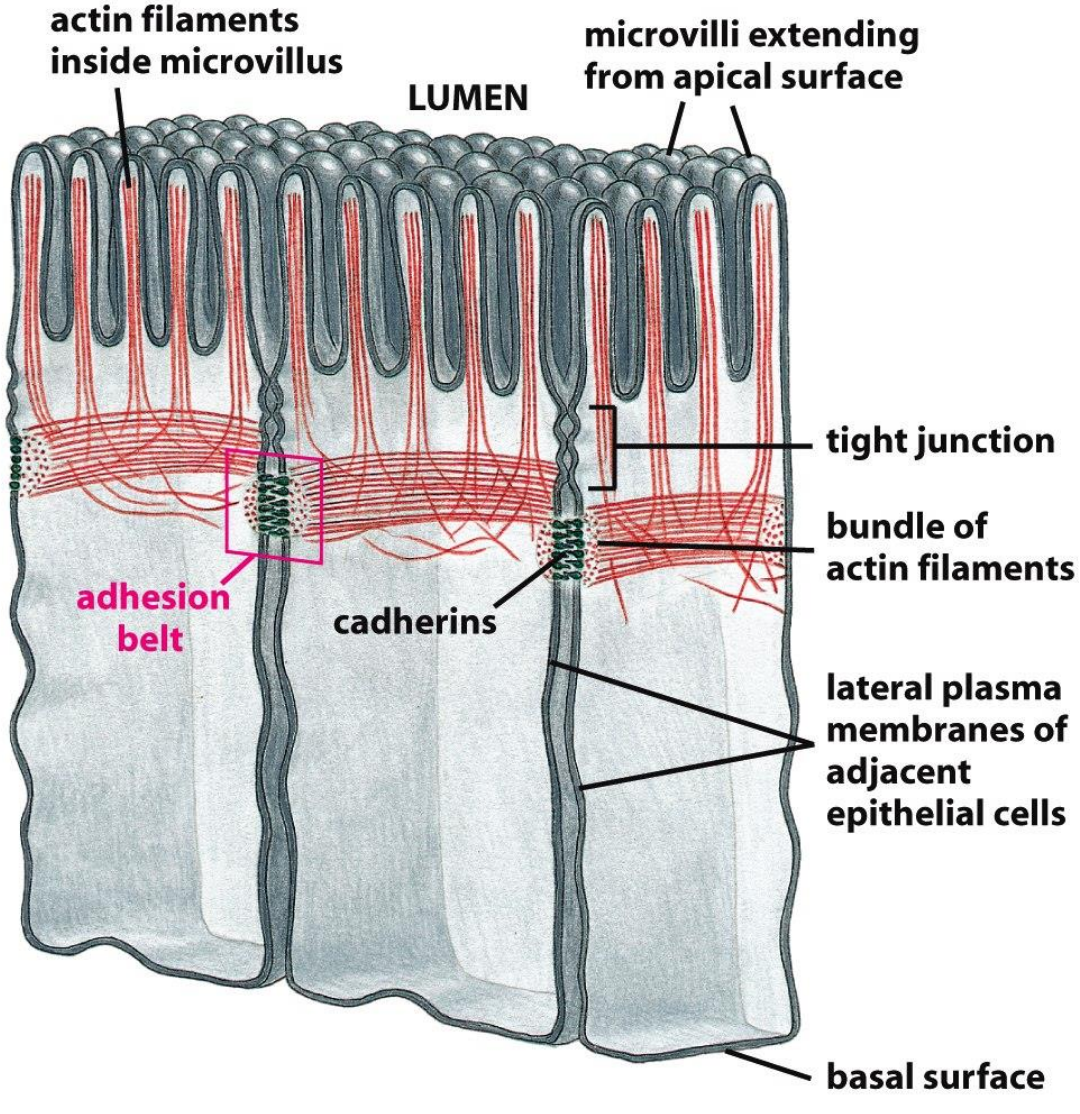



Figure 19-9a Molecular Biology of the Cell 5/e (© Garland Science 2008)

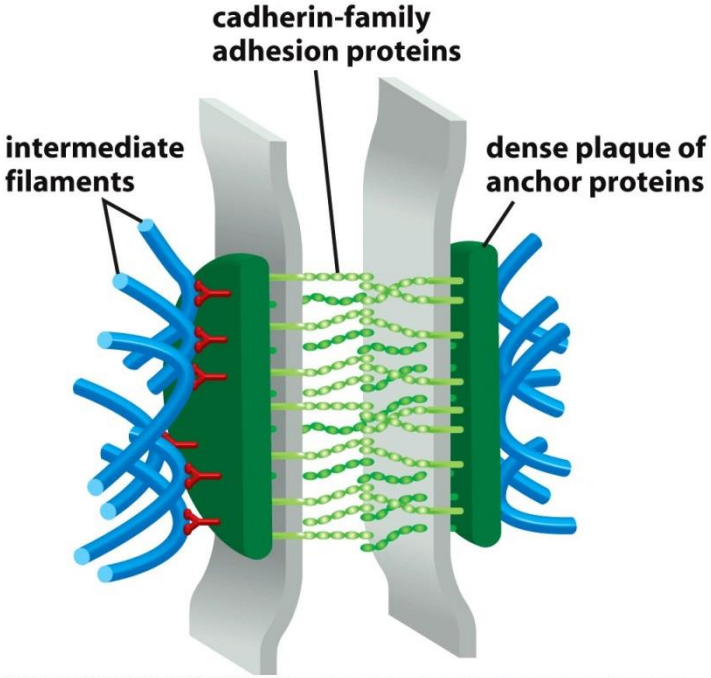


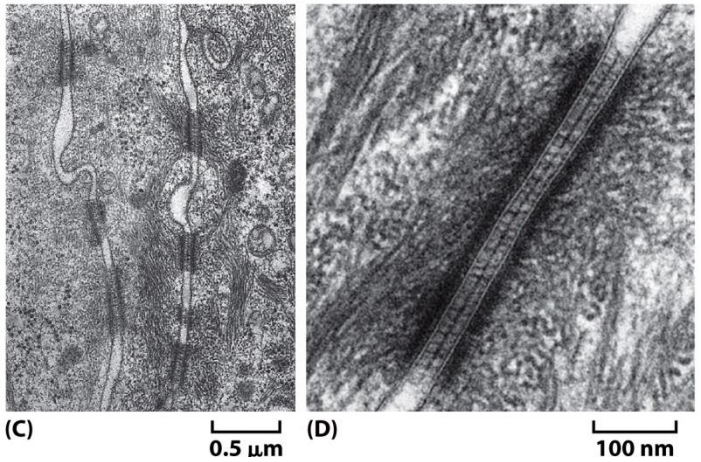
# Cadherin for cell junction

## Adherens junctions




## Desmosomes



# Sellectins

They interact with carbohydrates from the other cell membrane and are also calcium dependent.

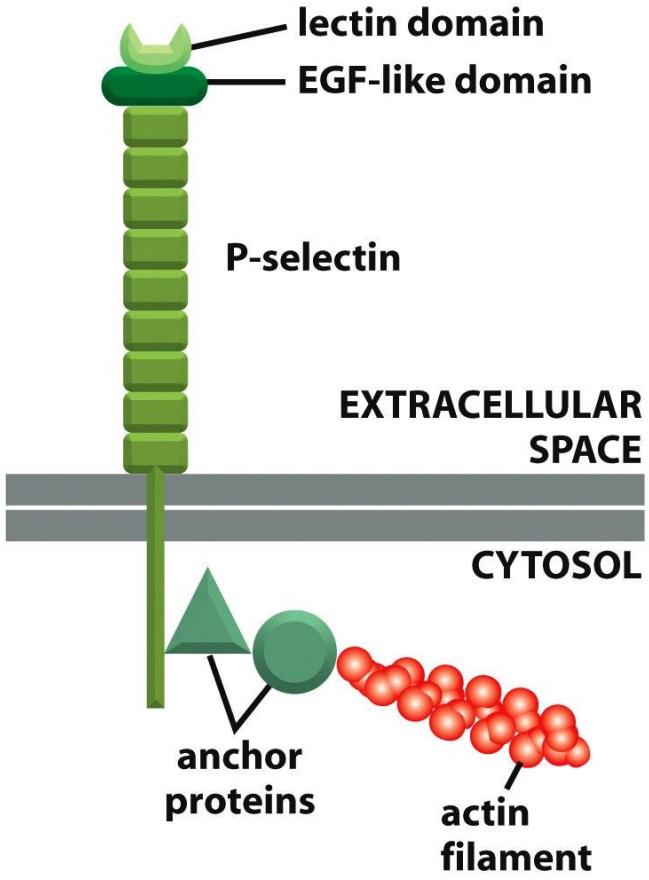



Figure 19-19a Molecular Biology of the Cell 5/e (© Garland Science 2008)

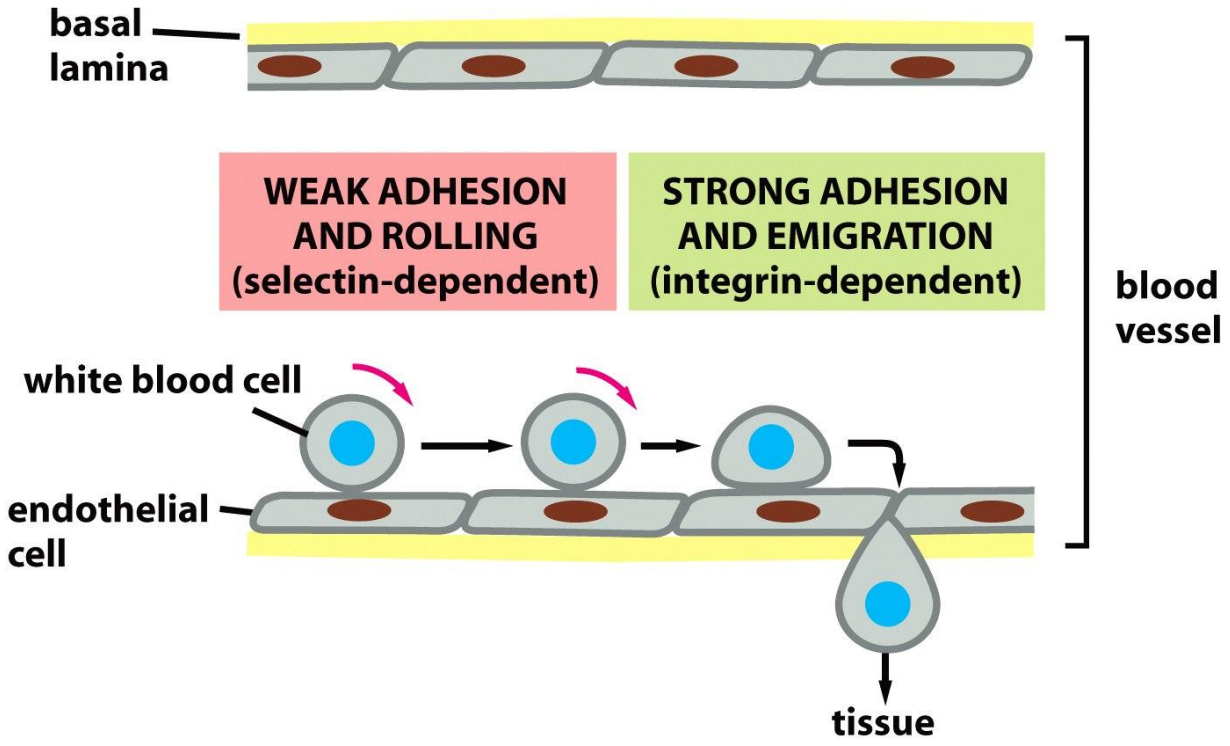



Figure 19-19b Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Immunoglobulins for cell adhesion

These Ig-like do not present immune defense activity.

They are calcium independent proteins.

Intercellular cell adhesion molecules (ICAM), vascular (VCAM) and neural (NCAM) compose the set of Ig.

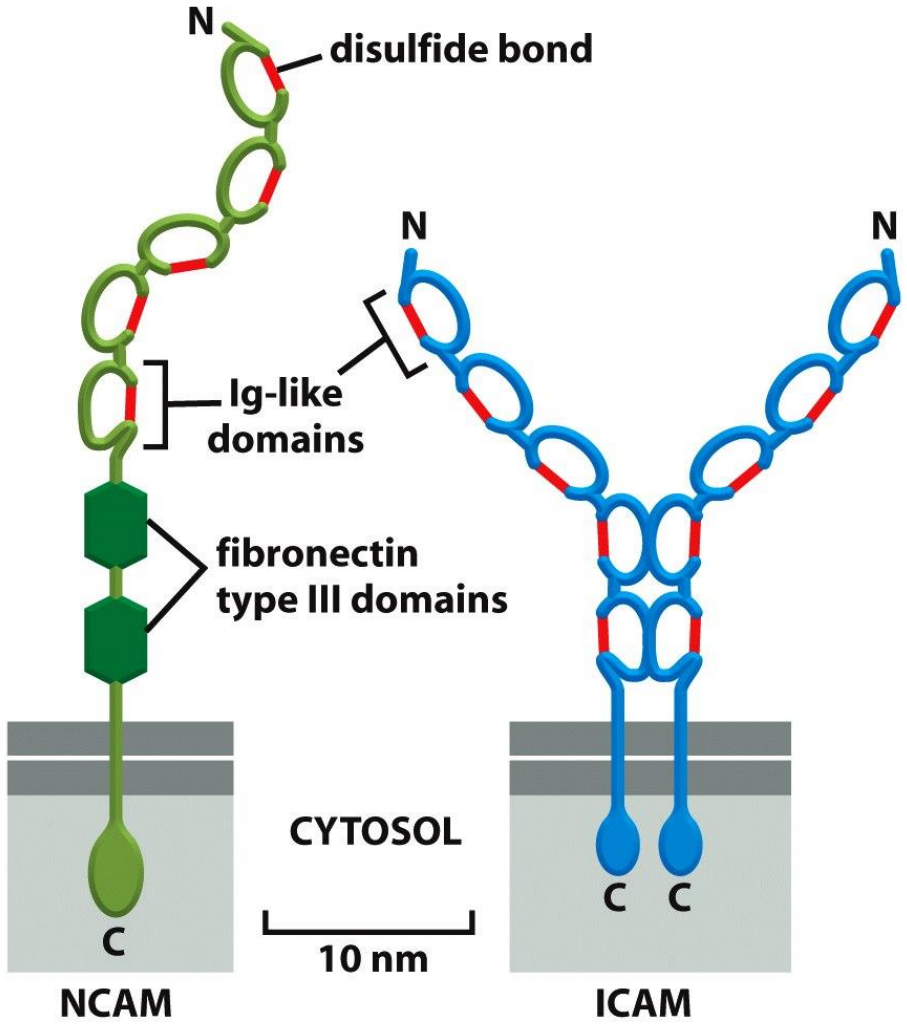


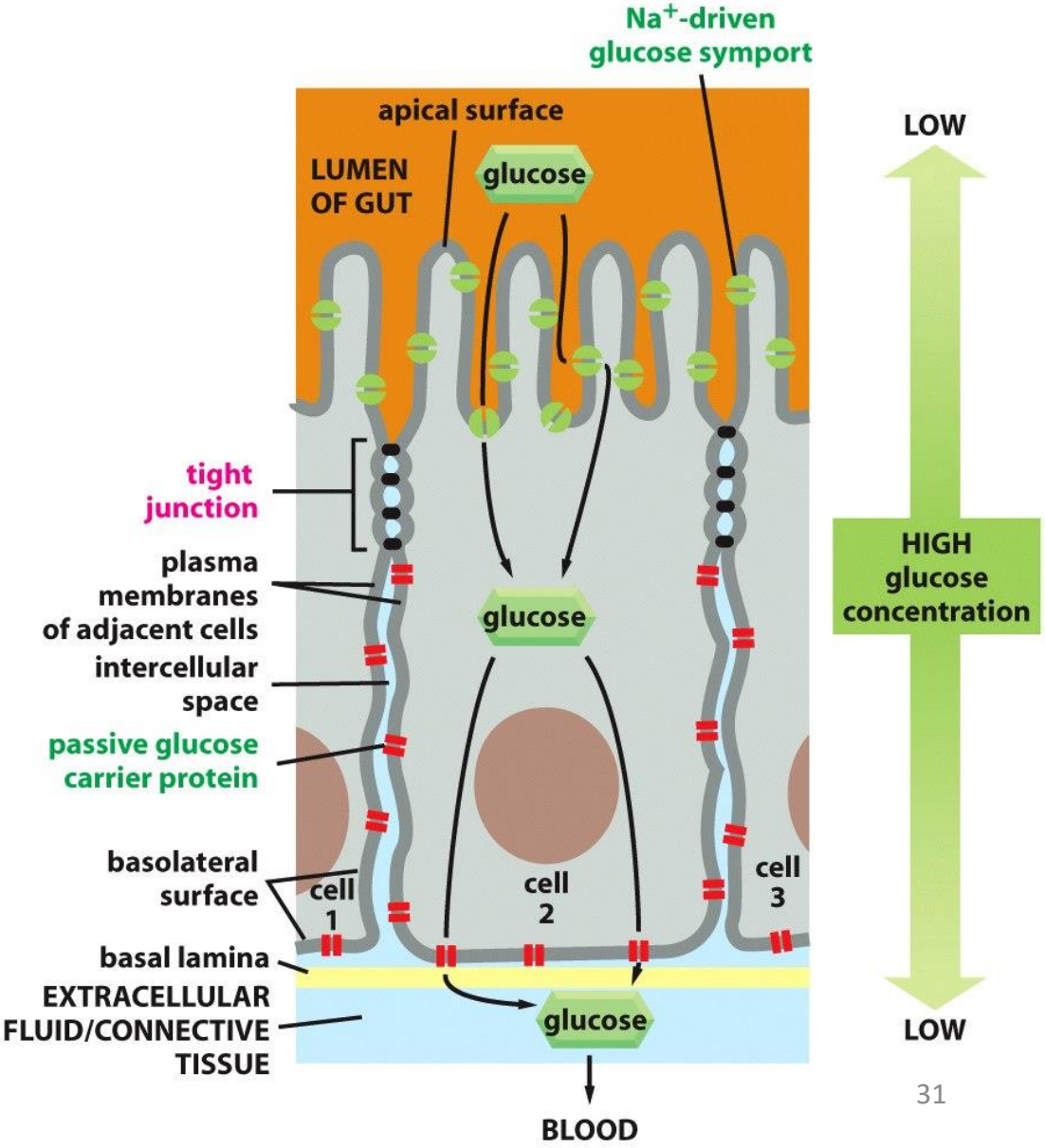

Figure 19-20 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Tight junctions

Claudins are the most important proteins for this junctions.

There are 24 claudins described in the human.

Occludin and Tricellulin are also found.



# Tight junctions

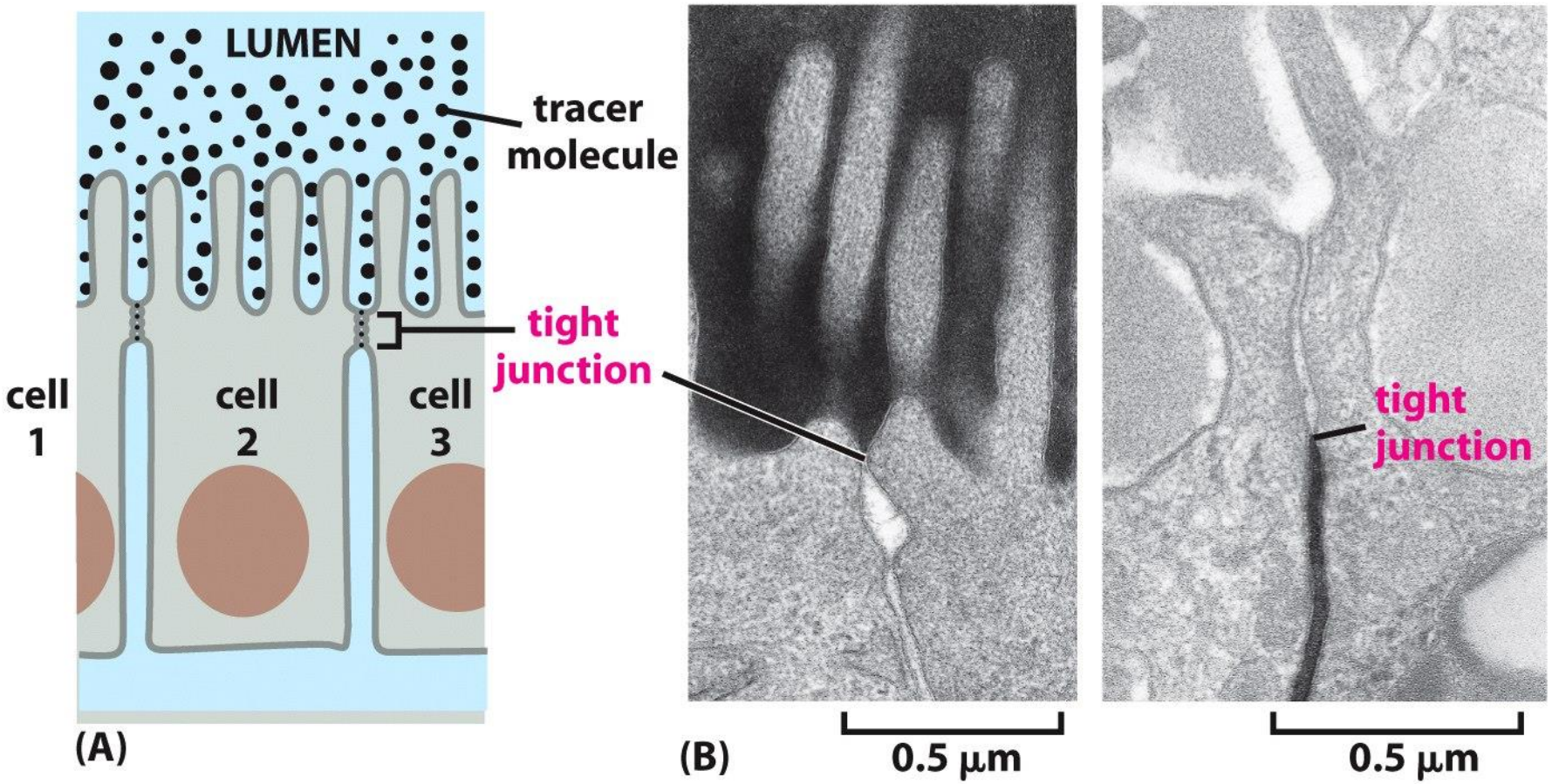



Figure 19-24 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Cell junction and polarization

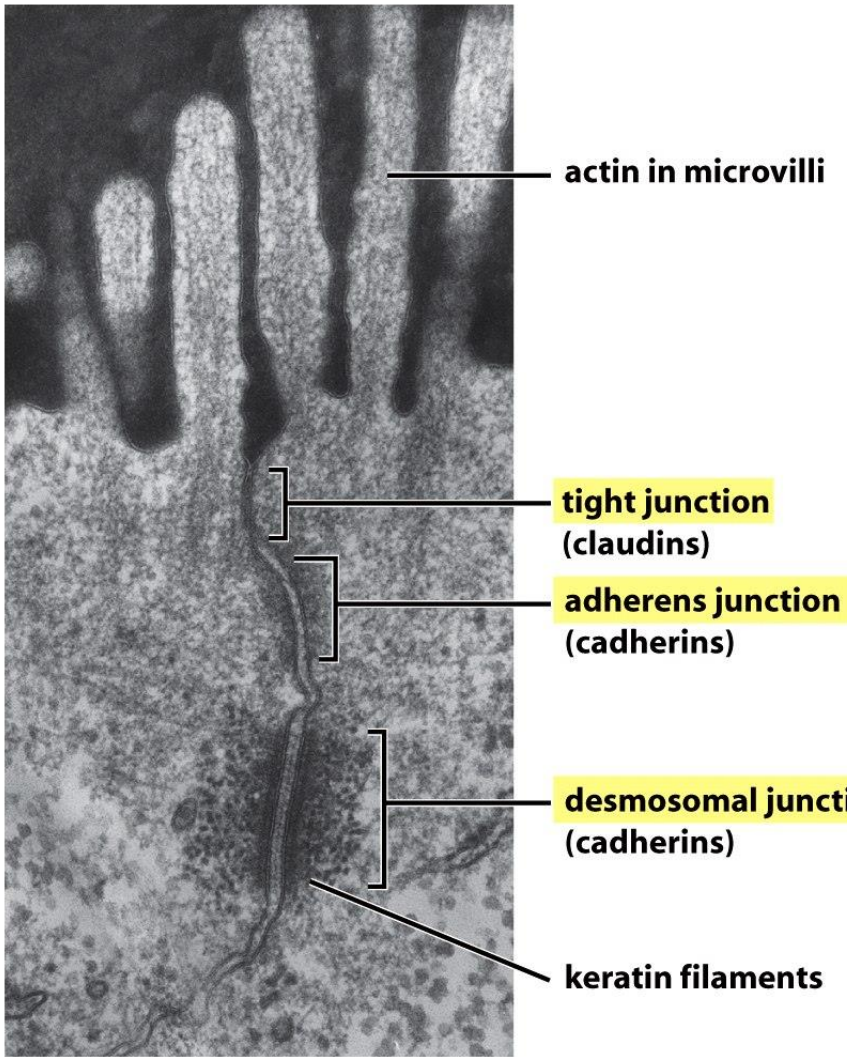



Figure 19-27 Molecular Biology of the Cell 5/e (© Garland Science 2008)

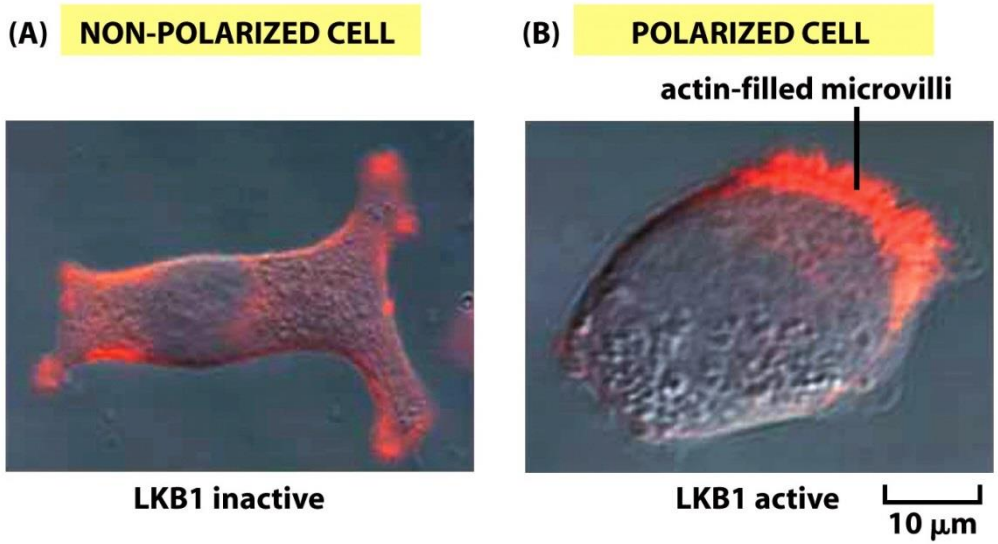



Figure 19-30 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Epithelial polarity

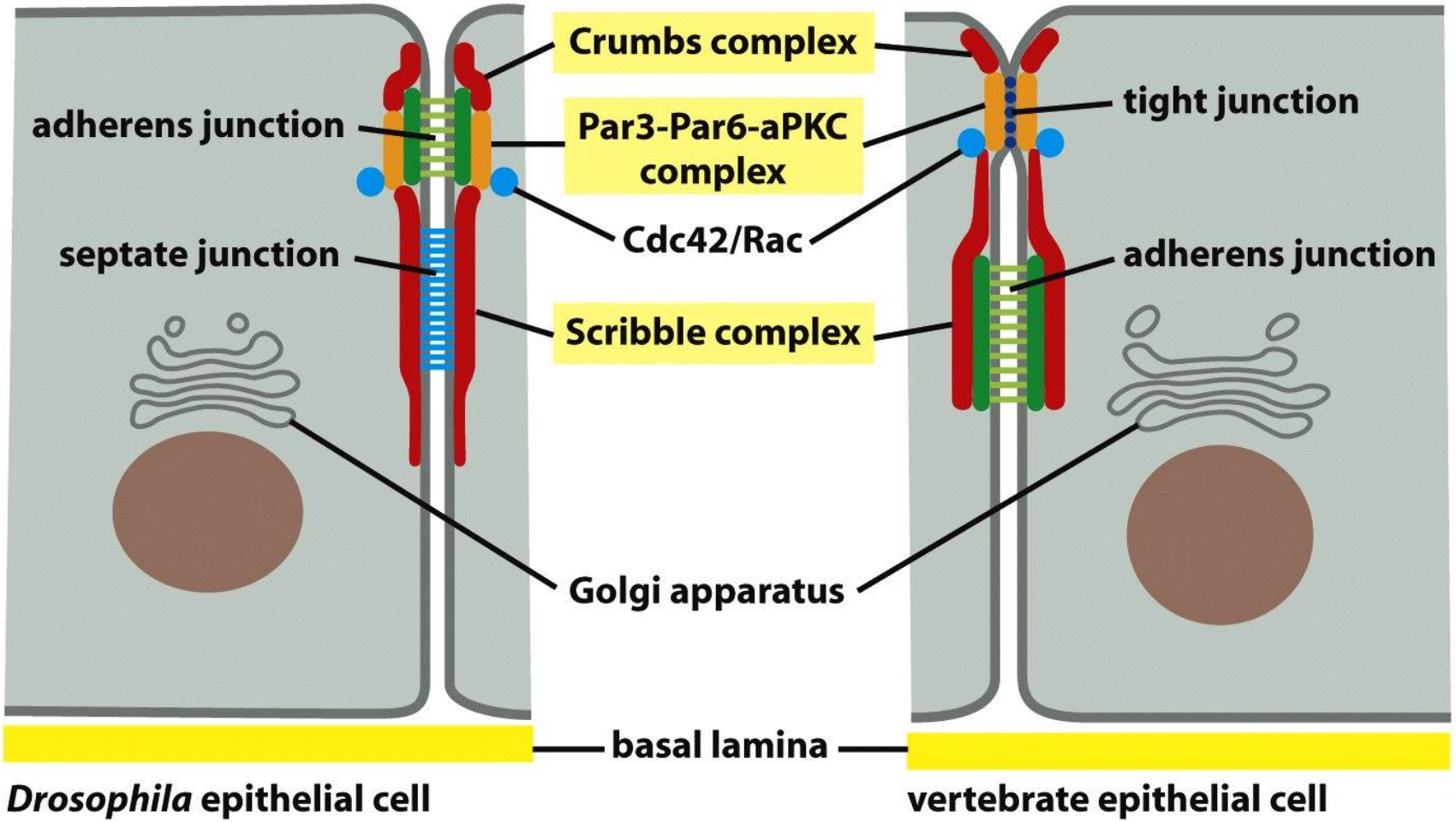



Figure 19-31 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Planar cell polarity

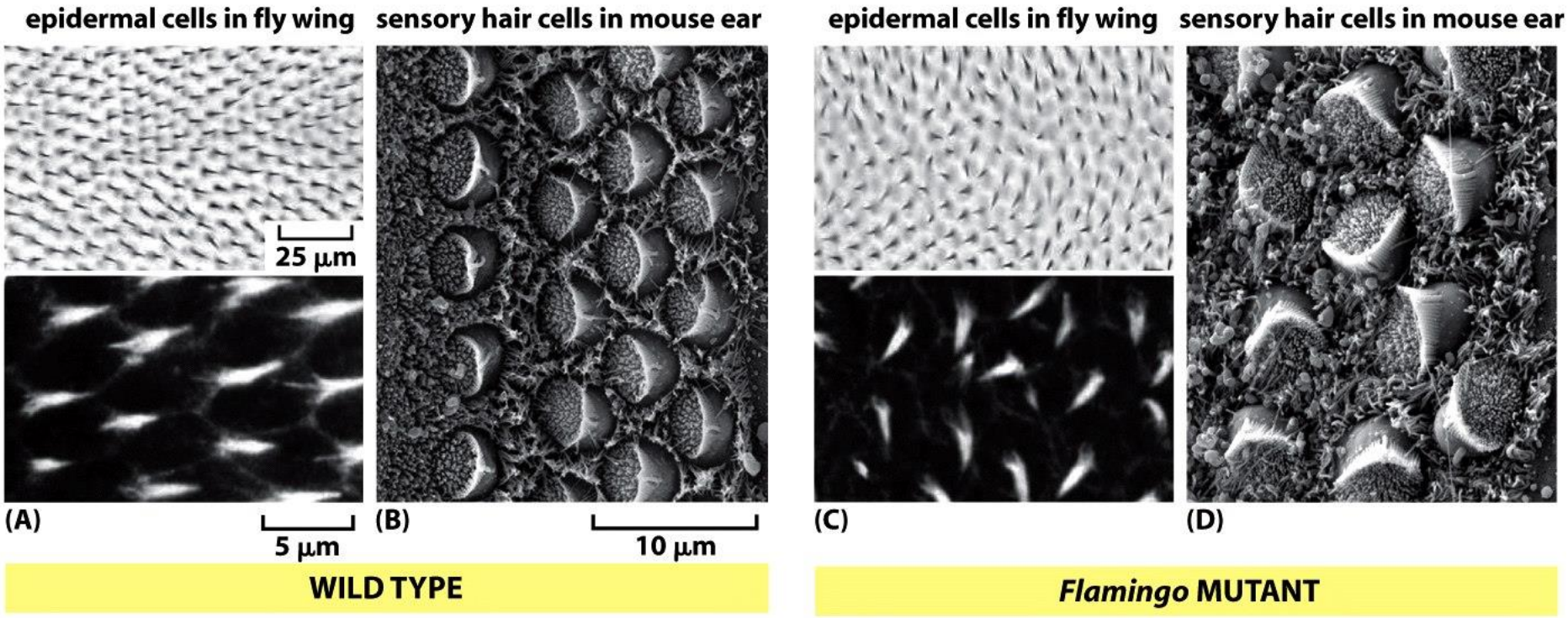



Figure 19-32 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Passage gateways – gap junctions

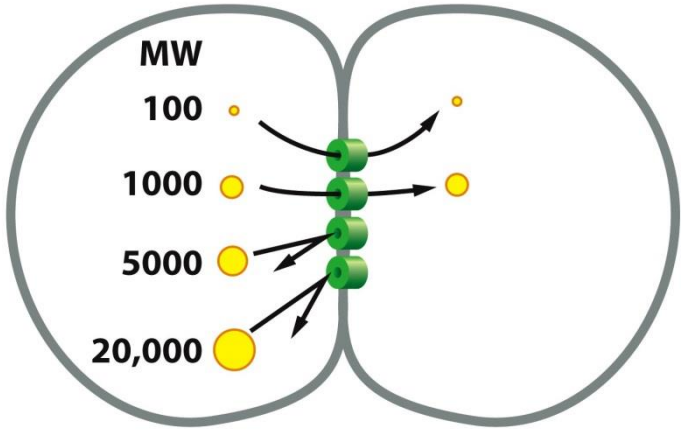



Figure 19-33 Molecular Biology of the Cell 5/e (© Garland Science 2008)

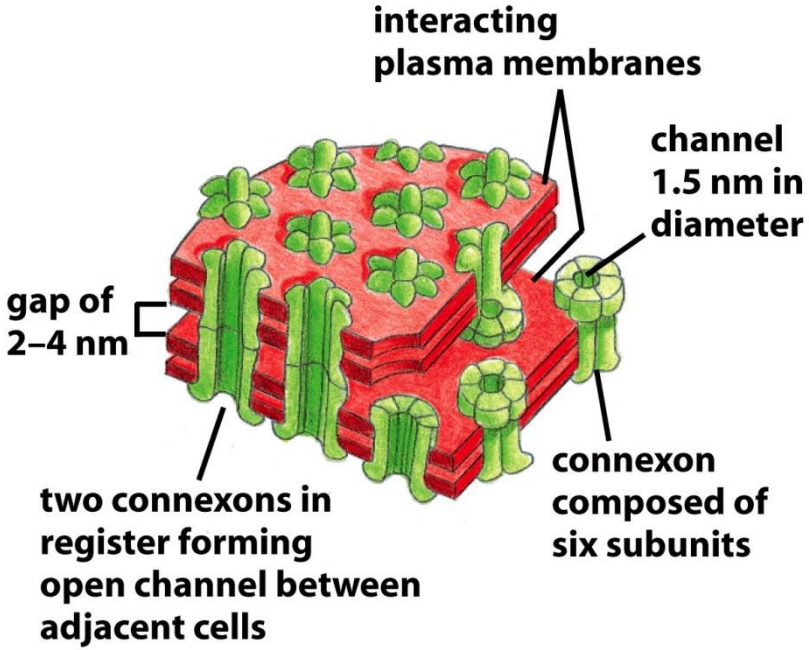



Figure 19-34a Molecular Biology of the Cell 5/e (© Garland Science 2008)

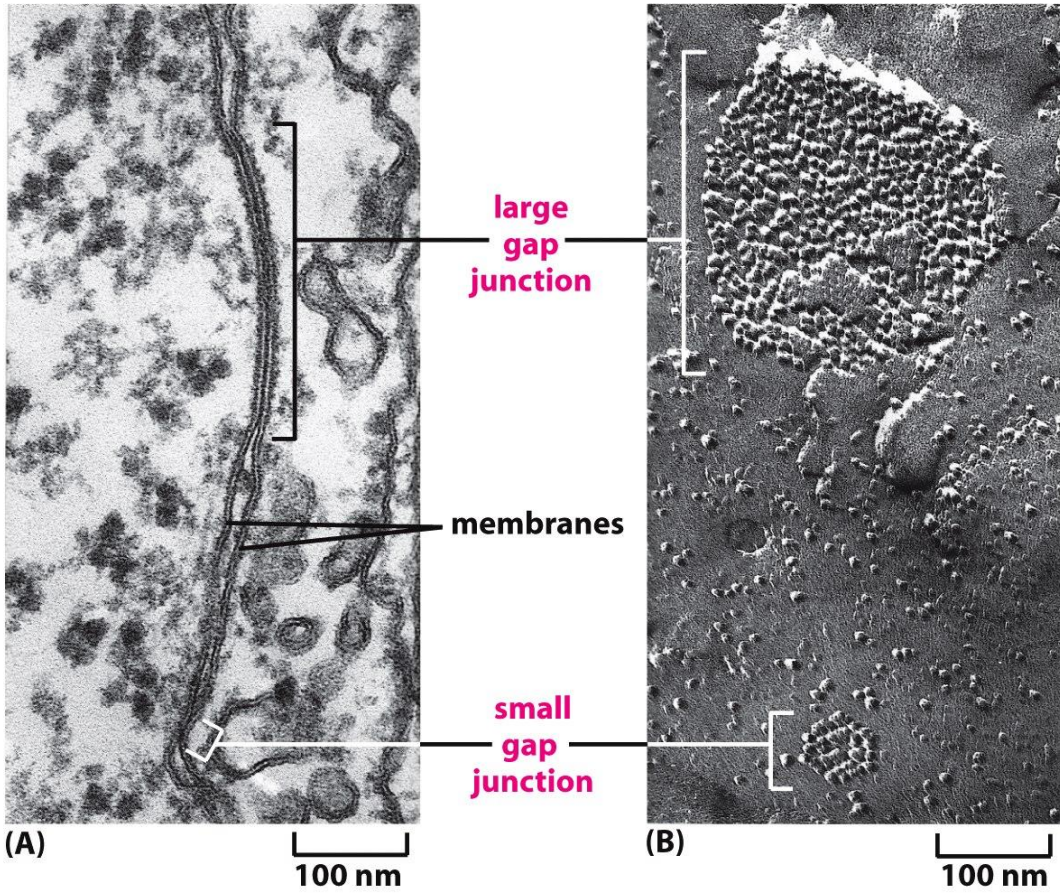



Figure 19-35 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Cell-matrix contacts - Integrins

These are them most important adhesion proteins for cell-matrix contacts.

At least 24 different types of integrins were already described in human cells (8 β–chain genes and 18 α–chain genes ).

All follow the same dimeric structure with α and β subunits.

They mediate the anchorage dependence of cells.

# Integrin and hemidesmosomes

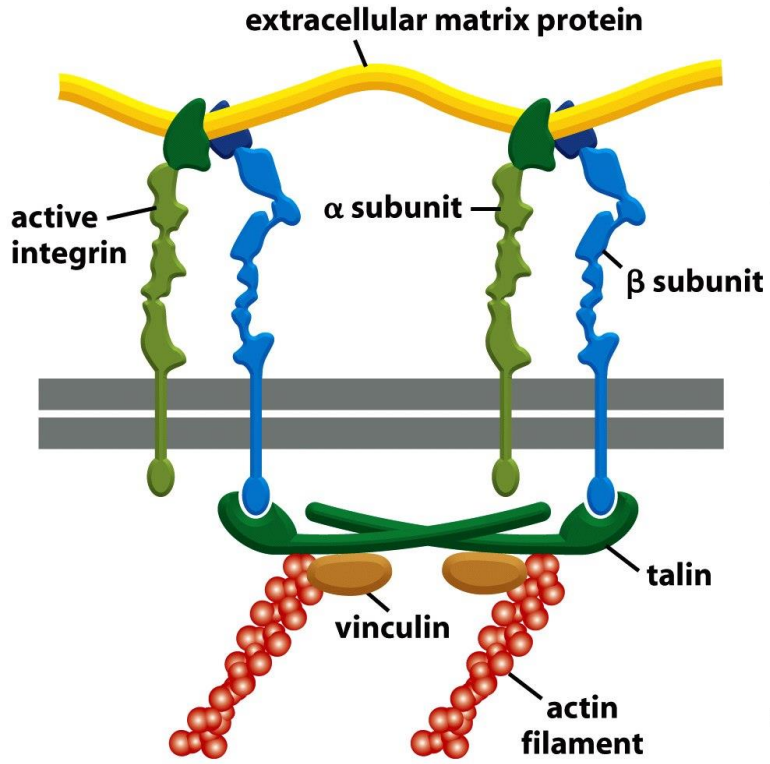



Figure 19-45 Molecular Biology of the Cell 5/e (© Garland Science 2008)

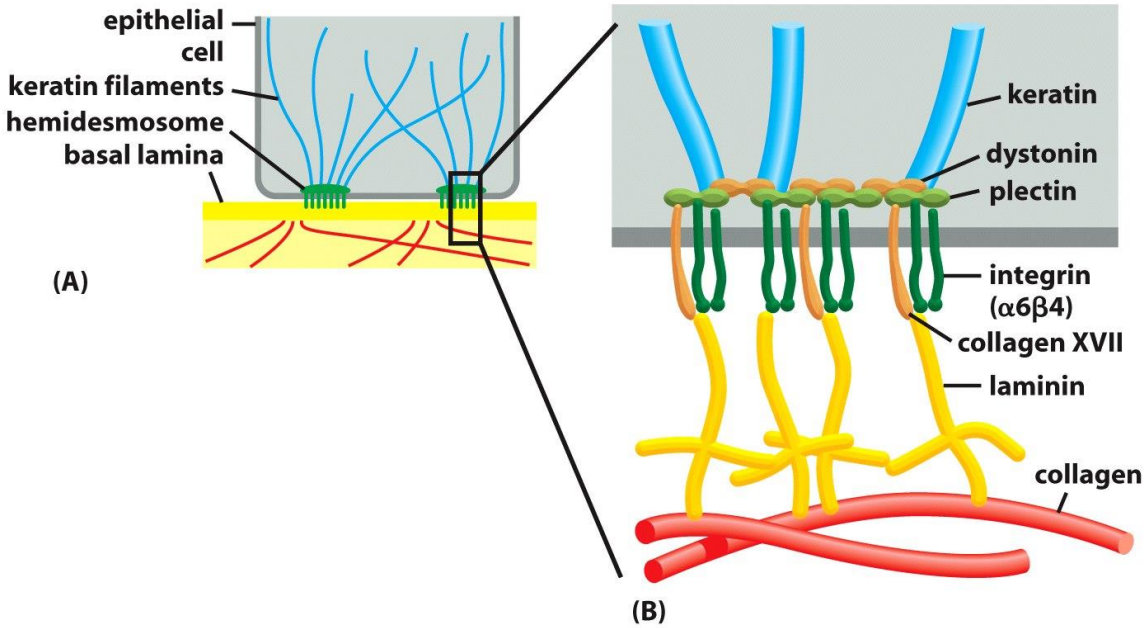



Figure 19-46 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Integrin activation

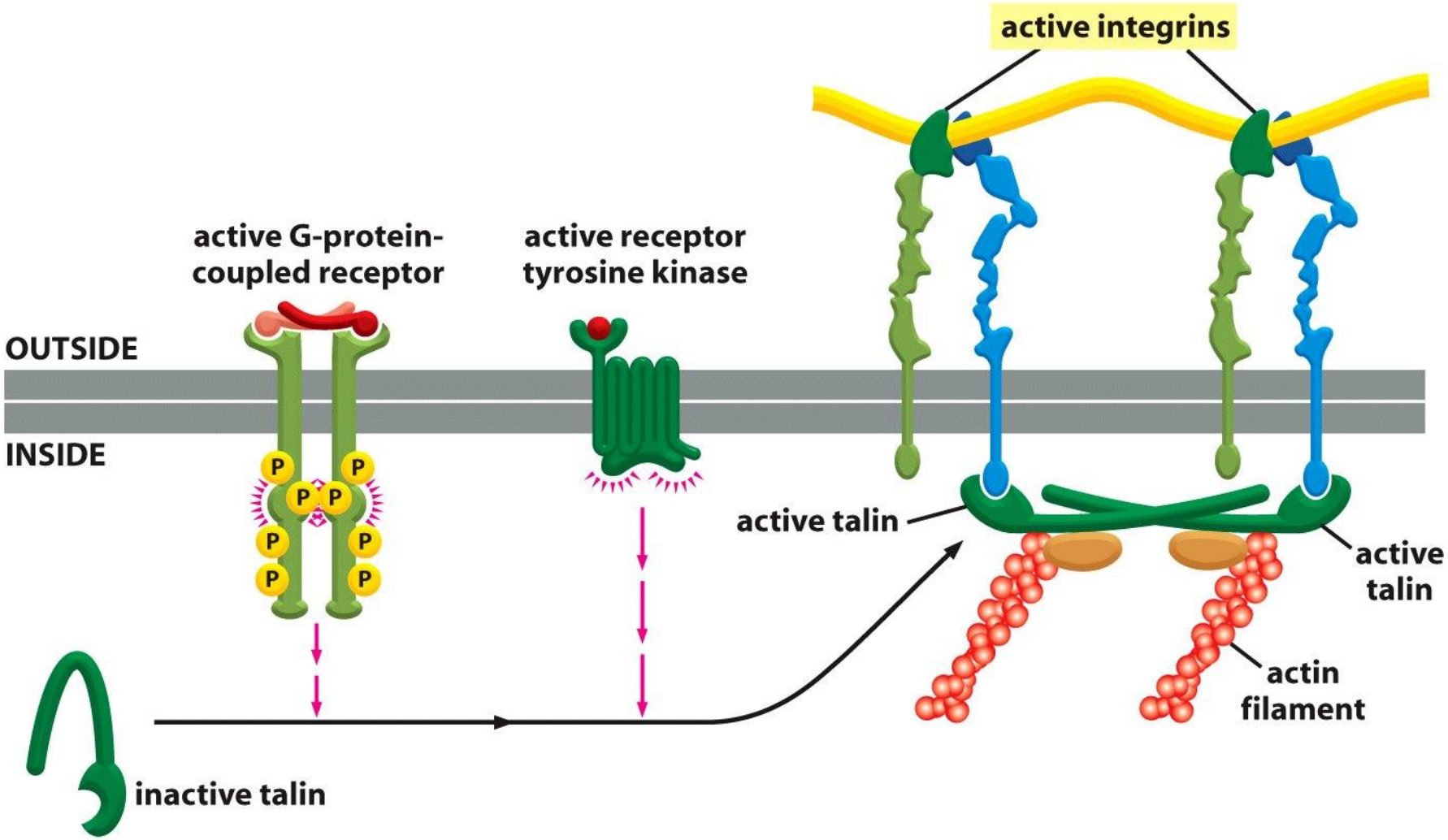



Figure 19-49 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Integrin and anchorage dependence

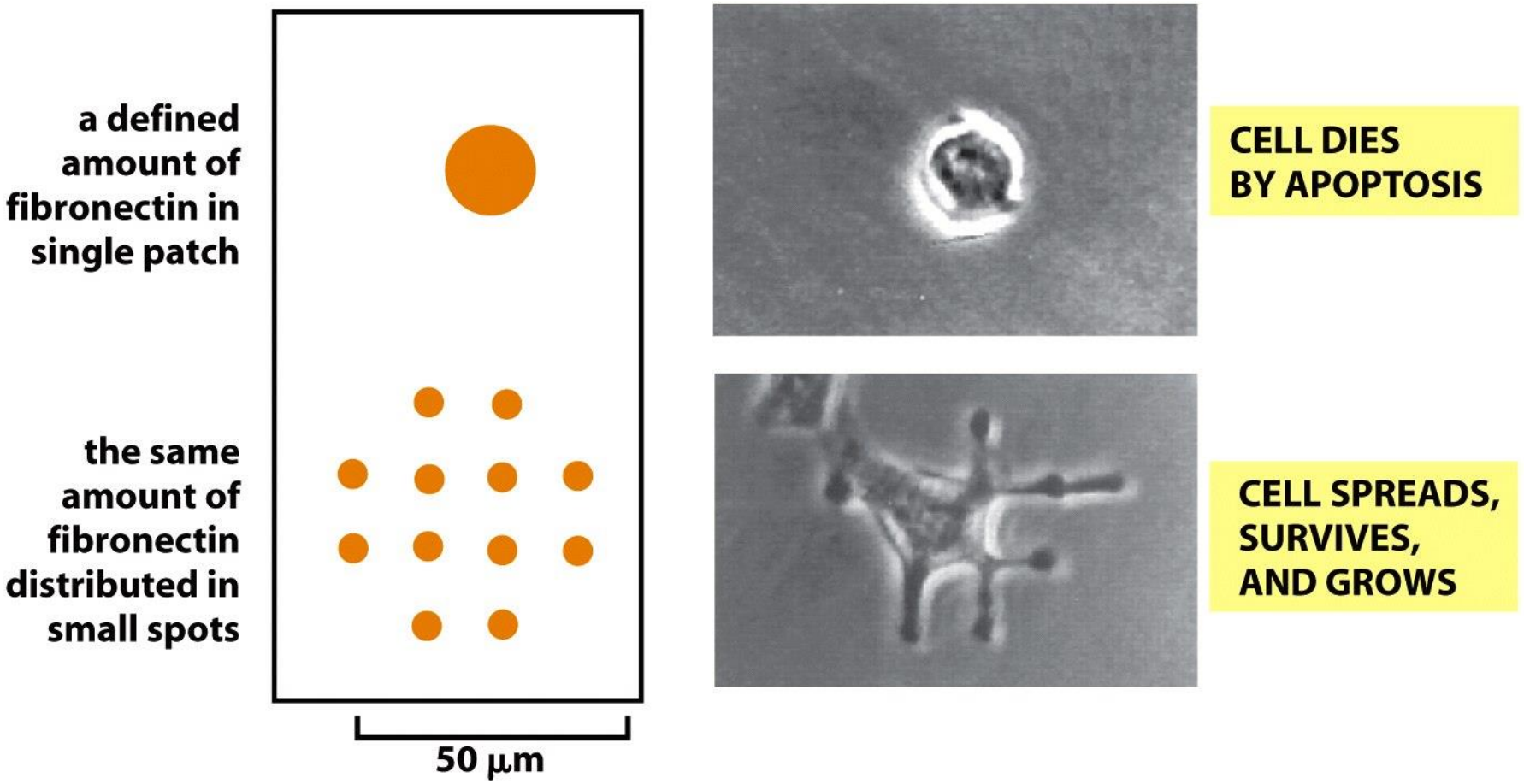



Figure 19-51 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Integrin and cell morphology

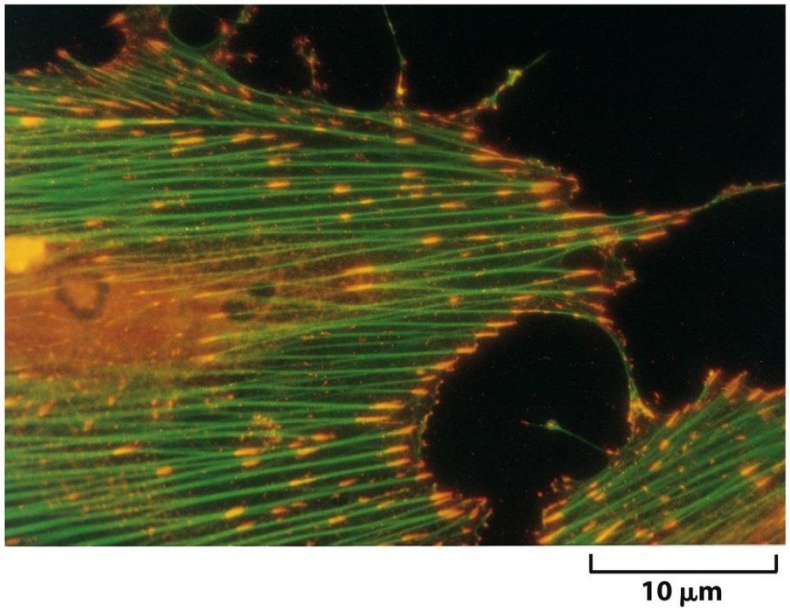



Figure 19-52a Molecular Biology of the Cell 5/e (© Garland Science 2008)

Phosphotyrosine (active protein): red
Actin: green

FAK: focal adhesion kinase

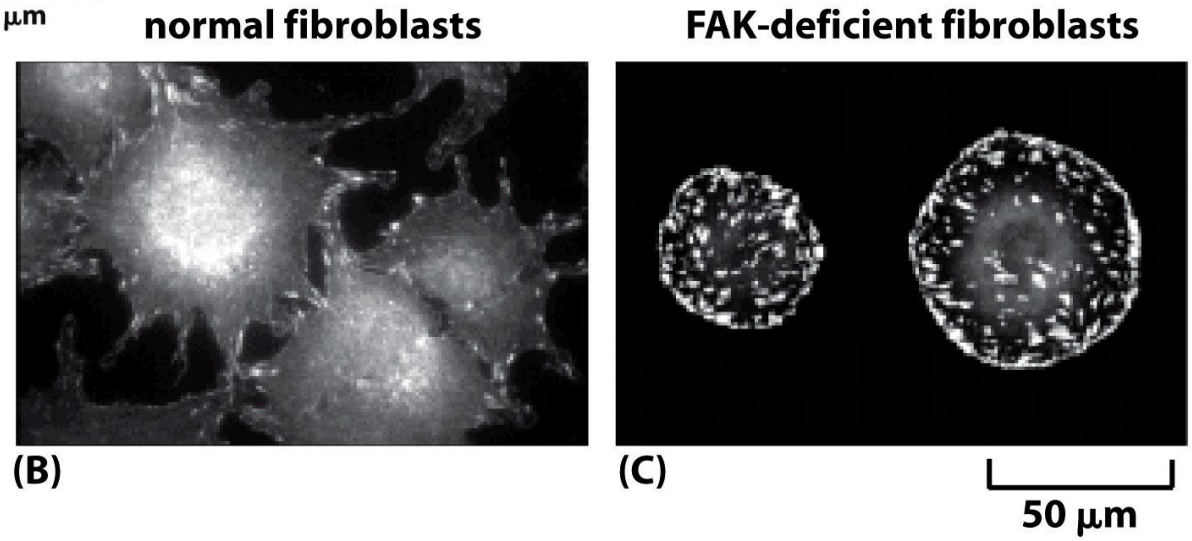



Figure 19-52bc Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Classification of integrins

**Table 19–4** Some Types of Integrins

| INTEGRIN | LIGAND* | DISTRIBUTION | PHENOTYPE WHEN α SUBINUT IS MUTATED | PHENOTYPE WHEN β SUBUNIT IS MUTATED |
|---|---|---|---|---|
| α5β1 | fibronectin | ubiquitous | death of embryo; defects in blood vessels, somites, neural crest | early death of embryo (at implantation) |
| α6β1 | laminin | ubiquitous | severe skin blistering; defects in other epithelia also | early death of embryo (at implantation) |
| α7β1 | laminin | muscle | muscular dystrophy; defective myotendinous junctions | early death of embryo (at implantation) |
| αLβ2 (LFA1) | Ig superfamily counterreceptors (ICAM) | white blood cells | impaired recruitment of leucocytes | leucocyte adhesion deficiency (LAD) impaired inflammatory responses; recurrent life-threatening infections |
| αIIbβ3 | fibrinogen | platelets | bleeding; no platelet aggregation (Glanzmann's disease) | bleeding; no platelet aggregation (Glanzmann's disease); mild osteopetrosis |
| α6β4 | laminin | hemidesmosomes in epithelia | severe skin blistering; defects in other epithelia also | severe skin blistering; defects in other epithelia also |

*Not all ligands are listed.

Table 19-4 Molecular Biology of the Cell 5/e (© Garland Science 2008)

# Cell adhesion molecules

**Table 19–5 Cell Adhesion Molecule Families**

| | SOME FAMILY MEMBERS | $Ca^{2+}$ OR $Mg^{2+}$ DEPENDENCE | HOMOPHILIC OR HETEROPHILIC | CYTOSKELETON ASSOCIATIONS | CELL JUNCTION ASSOCIATIONS |
|---|---|---|---|---|---|
| ***Cell–Cell Adhesion*** | | | | | |
| Classical cadherins | E, N, P, VE | yes | homophilic | actin filaments (via catenins) | adherens junctions, synapses |
| Desmosomal cadherins | desmoglein, desmocollin | yes | homophilic | intermediate filaments (via desmoplakin, plakoglobin, and plakophilin) | desmosomes |
| Ig family members | N-CAM, ICAM | no | both | unknown | neuronal and immunological synapses |
| Selectins (blood cells and endothelial cells only) | L-, E-, and P-selectins | yes | heterophilic | actin filaments | (no prominent junctional structure) |
| Integrins on blood cells | αLβ2 (LFA1) | yes | heterophilic | actin filaments | immunological synapses |
| ***Cell–Matrix Adhesion*** | | | | | |
| Integrins | many types | yes | heterophilic | actin filaments (via talin, paxillin, filamin, α-actinin, and vinculin) | focal adhesions |
| | α6β4 | yes | heterophilic | intermediate filaments (via plectin and dystonin) | hemidesmosomes |
| Transmembrane proteoglycans | syndecans | no | heterophilic | actin filaments | (no prominent junctional structure) |

Table 19-5 Molecular Biology of the Cell 5/e (© Garland Science 2008)