Chapter 16
The Cytoskeleton

Figure 16-1 Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-8 (part 1 of 2) Molecular Biology of the Cell (© Garland Science 2008)

**SINGLE PROTOFILAMENT: THERMALLY UNSTABLE**

- Breakage in middle breaks one bond
- Removal from one end breaks one bond

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Figure 16-8 (part 2 of 2) Molecular Biology of the Cell (© Garland Science 2008)

**MULTIPLE PROTOFILAMENTS: THERMALLY STABLE**

- Breakage in middle breaks 5 longitudinal bonds
- Removal from one end breaks one longitudinal and 2 lateral bonds
staggered long subunits: lateral contacts dominate

ROPE-LIKE PROPERTIES

Figure 16-9  Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-10  Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-11 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-12 Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-13 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-14a Molecular Biology of the Cell (© Garland Science 2008)
For $C_c(T) < C < C_c(D)$

treadmilling occurs
Table 16–1 Major Types of Intermediate Filament Proteins in Vertebrate Cells

<table>
<thead>
<tr>
<th>TYPES OF IF</th>
<th>COMPONENT POLYPEPTIDES</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>lamins A, B, and C</td>
<td>nuclear lamina (inner lining of nuclear envelope)</td>
</tr>
<tr>
<td>Vimentin-like</td>
<td>vimentin</td>
<td>many cells of mesenchymal origin</td>
</tr>
<tr>
<td></td>
<td>desmin</td>
<td>muscle</td>
</tr>
<tr>
<td></td>
<td>glial fibrillary acidic protein</td>
<td>glial cells (astrocytes and some Schwann cells)</td>
</tr>
<tr>
<td></td>
<td>peripherin</td>
<td>some neurons</td>
</tr>
<tr>
<td>Epithelial</td>
<td>type I keratins (acidic)</td>
<td>epithelial cells and their derivatives (e.g., hair and nails)</td>
</tr>
<tr>
<td></td>
<td>type II keratins (basic)</td>
<td></td>
</tr>
<tr>
<td>Axonal</td>
<td>neurofilament proteins (NF-L, NF-M, and NF-H)</td>
<td>neurons</td>
</tr>
</tbody>
</table>
Figure 16-21a,b. Molecular Biology of the Cell (© Garland Science 2008)
### Table 16–2 Drugs That Affect Actin Filaments and Microtubules

<table>
<thead>
<tr>
<th>ACTIN-SPECIFIC DRUGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Phalloidin</td>
<td>binds and stabilizes filaments</td>
</tr>
<tr>
<td>Cytochalasin</td>
<td>caps filament plus ends</td>
</tr>
<tr>
<td>Swinholide</td>
<td>severs filaments</td>
</tr>
<tr>
<td>Latrunculin</td>
<td>binds subunits and prevents their polymerization</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MICROTUBULE-SPECIFIC DRUGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxol</td>
<td>binds and stabilizes microtubules</td>
</tr>
<tr>
<td>Colchicine, colcemid</td>
<td>binds subunits and prevents their polymerization</td>
</tr>
<tr>
<td>Vinblastine, vincristine</td>
<td>binds subunits and prevents their polymerization</td>
</tr>
<tr>
<td>Nocodazole</td>
<td>binds subunits and prevents their polymerization</td>
</tr>
</tbody>
</table>

Table 16-2. Molecular Biology of the Cell (© Garland Science 2008)

**Figure 16-23a** Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-24a. Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-24b. Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-25a. Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-25b. Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-27b. Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-28. Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-29 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-30a Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-30b: Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-30c: Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-32a Molecular Biology of the Cell © Garland Science 2008

Figure 16-32b Molecular Biology of the Cell © Garland Science 2008
inactive ARP complex

activating factor

other proteins

Arp3

active ARP complex

Arp2

actin monomers

nucleated actin filament

minus end

plus end

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Figure 16-44 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-45a Molecular Biology of the Cell (© Garland Science 2008)
**Figure 16-49a** Molecular Biology of the Cell (© Garland Science 2008)

- **Actin filaments and α-actinin**
- **Contractile bundle**
  - Loose packing allows myosin-II to enter bundle

- **Actin filaments and fimbrin**
- **Parallel bundle**
  - Tight packing prevents myosin-II from entering bundle

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**Figure 16-49b** Molecular Biology of the Cell (© Garland Science 2008)

- **100 nm**

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Figure 16-51 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-52 Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-53 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-54a Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-57 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-58a Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-58b Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-59 Molecular Biology of the Cell (© Garland Science 2008)
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) 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.
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Figure 16-62 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-63 Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-64b. Molecular Biology of the Cell (© Garland Science 2008)

attachment to cargo or another microtubule

Figure 16-64c. Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-65 Molecular Biology of the Cell (© Garland Science 2008)
**Figure 16-65 (part 2 of 2)**

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**Figure 16-66**

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Figure 16-72a Molecular Biology of the Cell (© Garland Science 2008)

INACTIVE STATE: (light chains not phosphorylated)

ACTIVE STATE: (light chains phosphorylated)

Figure 16-72b Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-73a  Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-73b  Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-74b. Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-74c,d. Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-77 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-77a Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-78a. Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-78b. Molecular Biology of the Cell (© Garland Science 2008)
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(A) IN ISOLATED DOUBLET MICROTUBULES: DYNEIN PRODUCES MICROTUBULE SLIDING

(B) IN NORMAL FLAGELLUM: DYNEIN CAUSES MICROTUBULE BENDING

IN ISOLATED DOUBLET MICROTUBULES: DYNEIN PRODUCES MICROTUBULE SLIDING

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Figure 16-86 Molecular Biology of the Cell © Garland Science 2008

Figure 16-87 Molecular Biology of the Cell © Garland Science 2008
Figure 16-92a–c. Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-92d. Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-93  Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-94  Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-98b. Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-99. Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-100  Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-101  Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-105 Molecular Biology of the Cell (© Garland Science 2008)

Figure 16-106 Molecular Biology of the Cell (© Garland Science 2008)
Figure 16-107 Molecular Biology of the Cell (© Garland Science 2008)

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Figure Q16-2 Molecular Biology of the Cell (© Garland Science 2008)

(A) EXPERIMENTAL SETUP

(B) POSITION OF KINESIN

Figure Q16-3 Molecular Biology of the Cell (© Garland Science 2008)