Costameres form rib-like bands around the circumference of the muscle fiber.

Extracellular glycoproteins connect the sarcolemma to the extracellular matrix.

Dystrophin connects the sarcolemma to f-actin of the cytoskeleton, which connects to the Z discs.

Connection between Z discs

Myofibril

Transmembrane proteins

Glycogen granules

Sarcoplasmic reticulum

Terminal cisterna

Transverse tubule (T tubule)

Z disk
(a)

Sarcomere

A band

H zone

I band

Thin filament

Thick filament

Z disk

M line

Z disk

I band

H zone

M line

Outer edge of A band

thin filaments only

thick filaments only

thick filaments linked with accessory proteins

thick and thin filaments overlap

Zona control vacuole

43 nm

14.3 nm

120°
Equal and opposite forces by thin filaments; net force = 0
**Figure 17.5 Molecular interactions that underlie muscle contraction**

The myosin head cross-bridges interact with G-actin monomers to provide the molecular basis of contraction. Each cross-bridge goes through several cycles during a single contraction. Each of the two heads of a myosin molecule has an actin-binding site and an ATP-binding site where ATP is hydrolyzed. The two myosin heads function independently. During contraction, only one head of each pair binds to actin at a time. Structural studies suggest that no more than four myosin heads can attach over a span of seven G-actin monomers. Single-molecule studies suggest that each myosin head displaces the actin filament by about 10 to 12 nm.
1. The action potential in a motor neuron triggers exocytosis of ACh.

2. Ligand-gated channels open, and the net inward movement of Na⁺ initiates an action potential.

3. The action potential propagates over the cell membrane and depolarizes the tubules.

4. Depolarization of the voltage-sensitive DHPR causes a conformational change that opens the RyR calcium channels of the SR.

5. Ca²⁺ ions bind to troponin, and tropomyosin moves to expose myosin-binding sites on actin.

6. Cross-bridges go through several cycles as long as Ca²⁺ remains bound to troponin.
(a) Vertebrate smooth muscle

Phasic contraction

- \( \text{Ca}^{2+} \)
- Cross-bridge phosphorylation
- Force

Stimulation

Tonic contraction

- \( \text{Ca}^{2+} \)
- Latch
- Cross-bridge phosphorylation

Stimulation

Time

(b) Mollusk catch muscle

Acetylcholine

Relaxed

Active state

Catch state

Relaxed

Serotonin

Ca\(^{2+}\)

Force
Striated skeletal muscle motor unit

Striated cardiac muscle syncytium

Smooth muscle syncytium (autonomic innervation)

Single-unit smooth muscle

Multiunit smooth muscle

Postganglionic axon of autonomic nervous system

Varicosity containing vesicles of transmitter Gap junction

Postganglionic axon of autonomic nervous system

Varicosity containing vesicles of transmitter
### Table 10-2 Characteristics of the major types of muscle fibers in vertebrates

<table>
<thead>
<tr>
<th>Property/component</th>
<th>Skeletal</th>
<th>Cardiac</th>
<th>Multi-unit</th>
<th>Single-unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible banding pattern</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Myosin thick filaments and actin thin filaments</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Tropomyosin and troponin</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Transverse tubules</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Sarcoplasmic reticulum</td>
<td>Well developed</td>
<td>Well developed</td>
<td>Very little</td>
<td>Very little</td>
</tr>
<tr>
<td>Mechanism of contraction</td>
<td>Sliding of thick and thin filaments past each other</td>
<td>Sliding of thick and thin filaments past each other</td>
<td>Sliding of thick and thin filaments past each other</td>
<td>Sliding of thick and thin filaments past each other</td>
</tr>
<tr>
<td>Innervation</td>
<td>Somatic nerves</td>
<td>Autonomic nerves</td>
<td>Autonomic nerves</td>
<td>Autonomic nerves</td>
</tr>
</tbody>
</table>

*Neurogenic muscles contract only when stimulated by synaptic input from a neuron. Myogenic muscles endogenously produce depolarizing membrane potentials, allowing them to contract independently of any neuronal input.

†SR, sarcoplasmic reticulum; ECF, extracellular fluid.

*Source: Adapted from Sherwood, 2001.*
### Table 10-1 Properties of twitch (phasic) fibers in mammalian skeletal muscles

<table>
<thead>
<tr>
<th>Property</th>
<th>Slow oxidative (type I)</th>
<th>Fast oxidative (type IIa)</th>
<th>Fast glycolytic (type IIb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber diameter</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force per cross-sectional area</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of contraction ($V_{\text{max}}$)</td>
<td></td>
<td>←</td>
<td></td>
</tr>
<tr>
<td>Myosin ATPase activity</td>
<td></td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Resistance to fatigue</td>
<td>↑</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>Number of mitochondria</td>
<td>↑</td>
<td></td>
<td>↑</td>
</tr>
<tr>
<td>Capacity for oxidative phosphorylation</td>
<td>↑</td>
<td></td>
<td>↓</td>
</tr>
<tr>
<td>Enzymes for anaerobic glycolysis</td>
<td>↑</td>
<td>←</td>
<td>↑</td>
</tr>
</tbody>
</table>

*Source: Adapted from Sherwood, 2001.*  
*Key = Low ← Intermediate ↑ High*