

The Muscular System



Pectoralis major
• Draws arm forward and toward the body

Serratus anterior
• Helps raise arm
• Contributes to pushes
• Draws shoulder blade forward

Biceps brachii
• Bends forearm at elbow

Rectus abdominus
• Compresses abdomen
• Bends backbone
• Compresses chest cavity

External oblique
• Lateral rotation of trunk
• Compresses abdomen

Adductor longus
• Flexes thigh
• Rotates thigh laterally
• Draws thigh toward body

Sartorius
• Bends thigh at hip
• Bends lower leg at knee
• Rotates thigh outward

Quadriceps group
• Flexes thigh at hips
• Extends leg at knee

Tibialis anterior
• Flexes foot toward knee

Deltoid
• Raises arm
Trapezius
• Lifts shoulder blade
• Braces shoulder
• Draws head back

Triceps brachii
• Straightens forearm at elbow

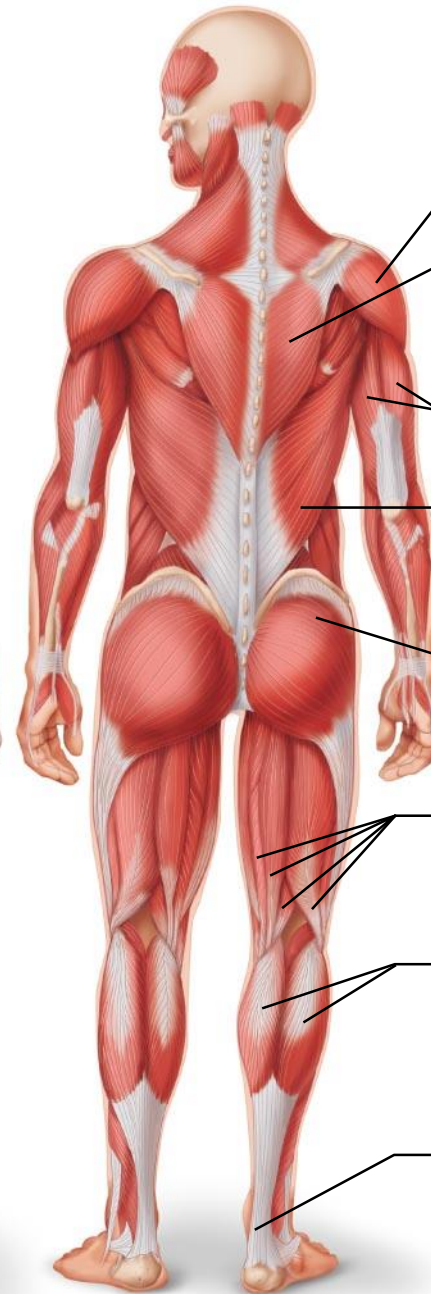
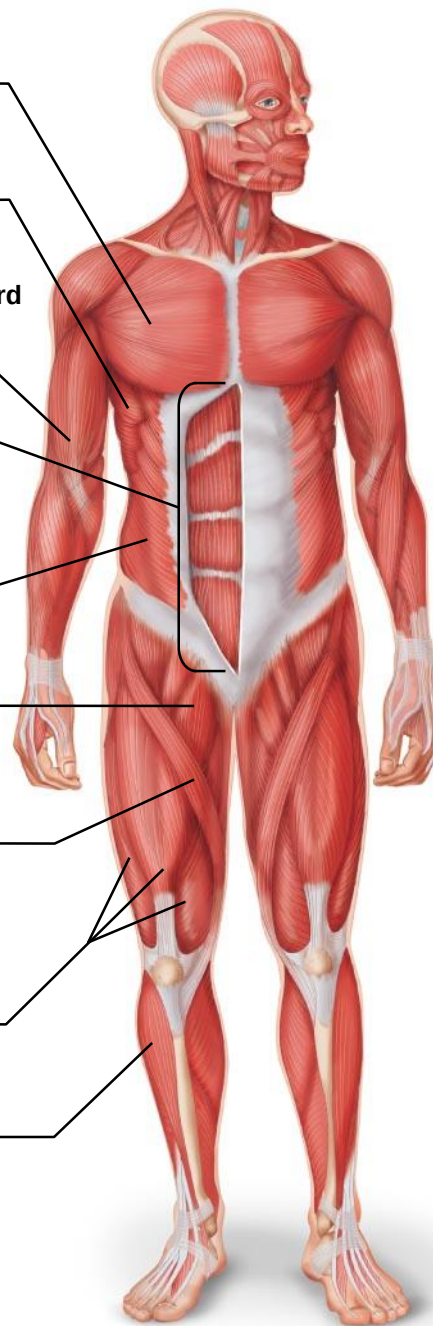
Latissimus dorsi
• Rotates and draws arm backward and toward body

Gluteus maximus
• Extends thigh
• Rotates thigh laterally

Hamstring group
• Draws thigh backward
• Bends knee

Gastrocnemius
• Bends lower leg at knee
• Bends foot away from knee

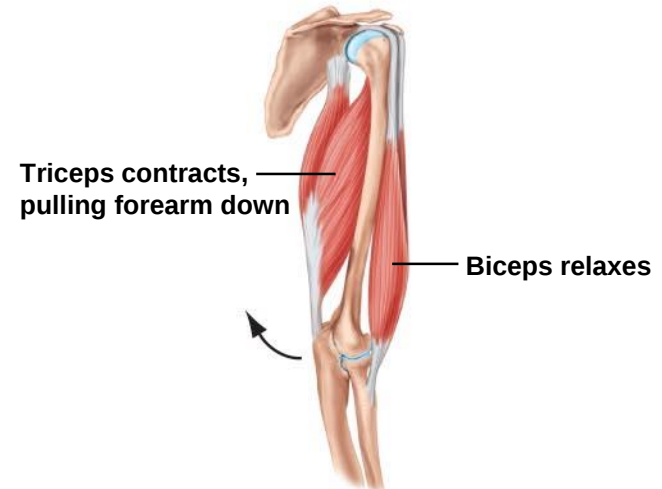
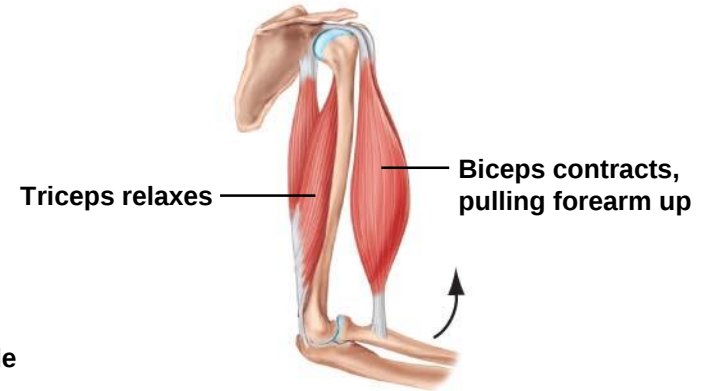
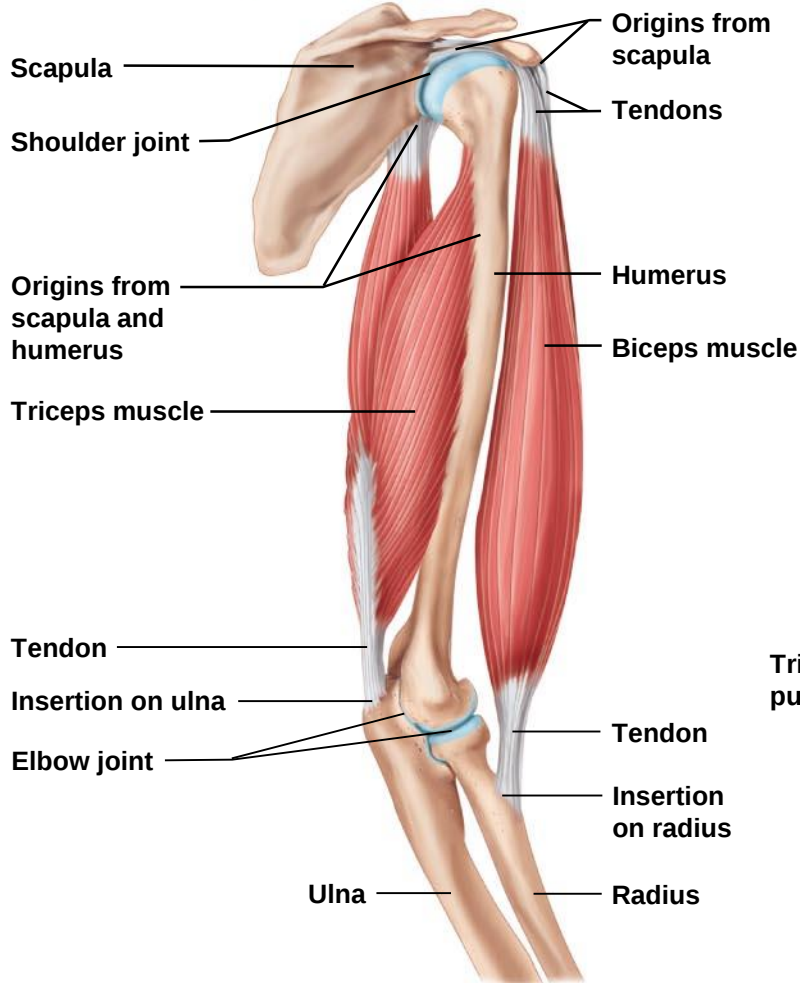
Achilles tendon
• Connects gastrocnemius muscle to heel



Muscle Function: Produce Movement or Generate Tension

- Principle function
 - **Contraction**
 - shortens distance between bones
 - Skeletal muscle moves bone
- Muscle groups
 - Synergistic
 - groups work together
 - Antagonistic
 - groups oppose each other

Origin / Insertion

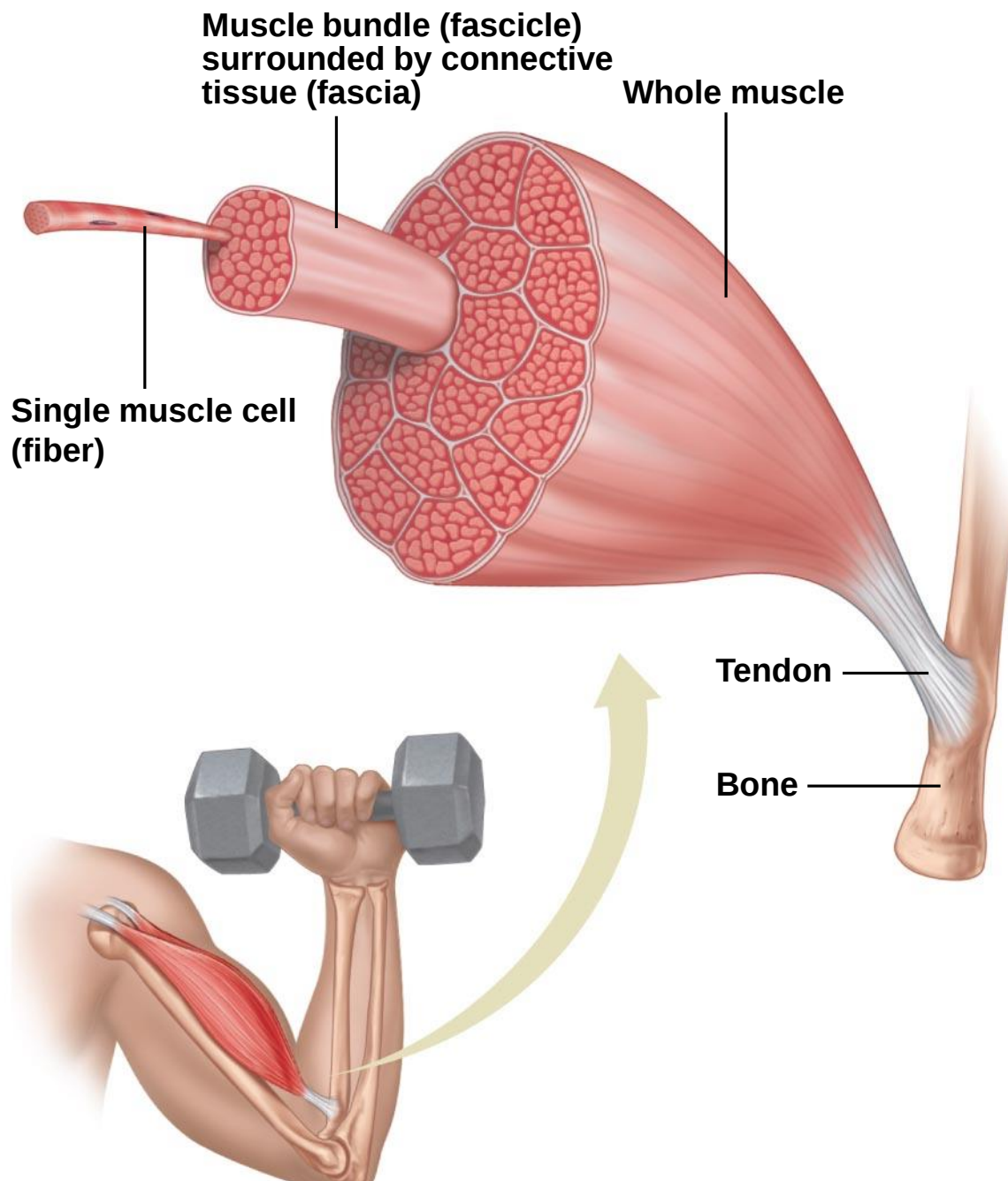


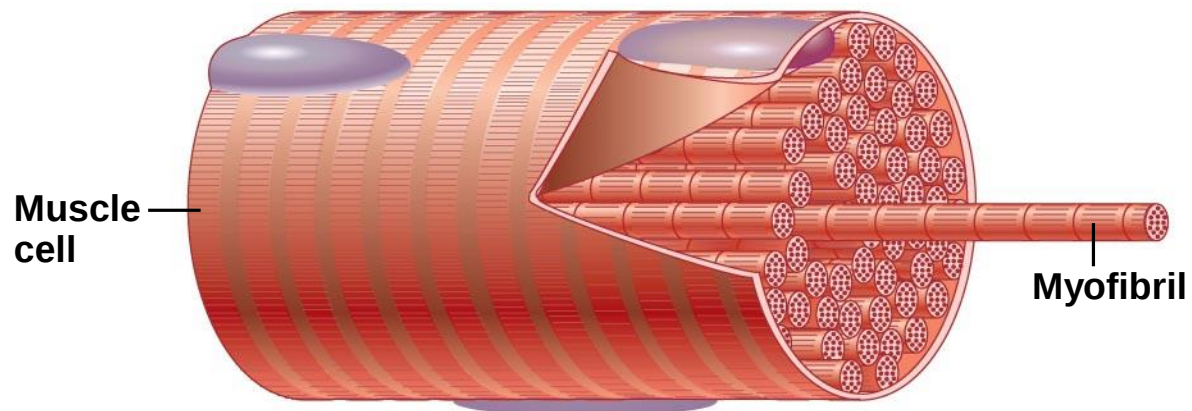
a) Origin and insertion. The point of attachment of a muscle to the stationary bone is its origin; the point of attachment to the movable bone is its insertion.

b) Movement. Antagonistic muscles produce opposite movements. The forearm bends when the biceps contracts and the triceps relaxes. The forearm straightens when the biceps relaxes and the triceps contracts.

Muscle Structure

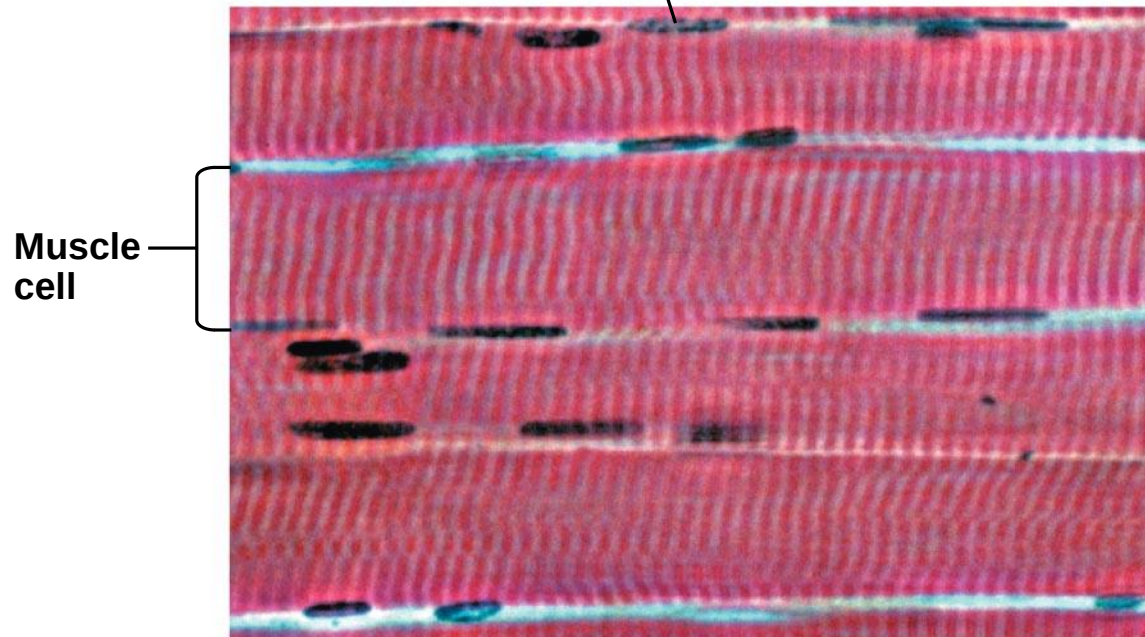
- Fascicles
 - Bundles of muscle fibers wrapped with connective tissue (fascia)
- Muscle fibers (muscle cells)
 - Long, tube shaped
 - Multinucleate
 - Packed with myofibrils
 - Myofibrils contain
 - Actin
 - Myosin





a) A single muscle cell contains many individual myofibrils and has more than one nucleus.

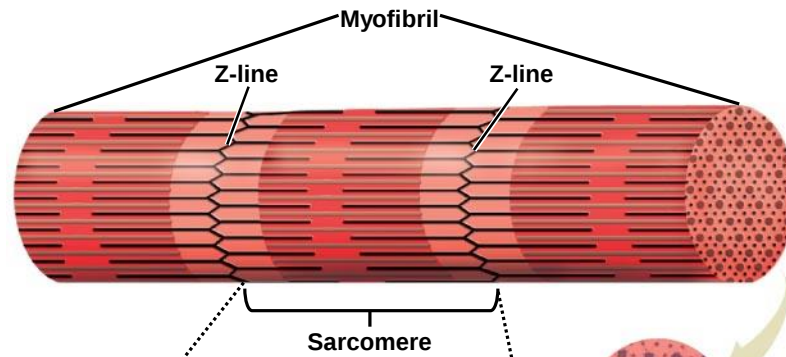
Nuclei



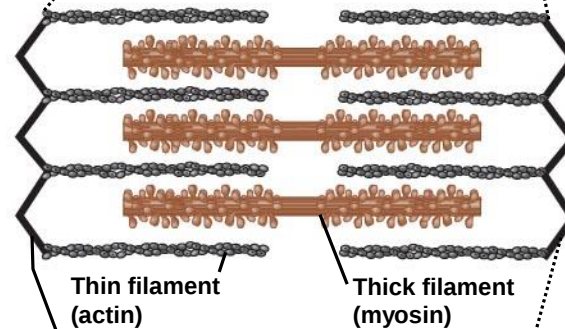
b) A photograph of portions of several skeletal muscle cells.

Skeletal Muscle Contractile Unit

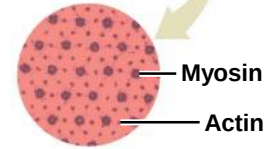
- **Sarcomere:** contractile unit
 - **Myosin**
 - forms thick filaments
 - **Actin**
 - forms thin filaments
- **Z Lines**
 - attachment points for sarcomeres
- Arrangement of filaments gives rise to **striated** appearance of skeletal muscle



a) A closer view of a section of a myofibril showing that it is composed of sarcomeres joined end to end at the Z-line



b) Sarcomeres contain thin filaments of actin that attach to the Z-lines and thicker filaments of myosin that span the gap between actin molecules.



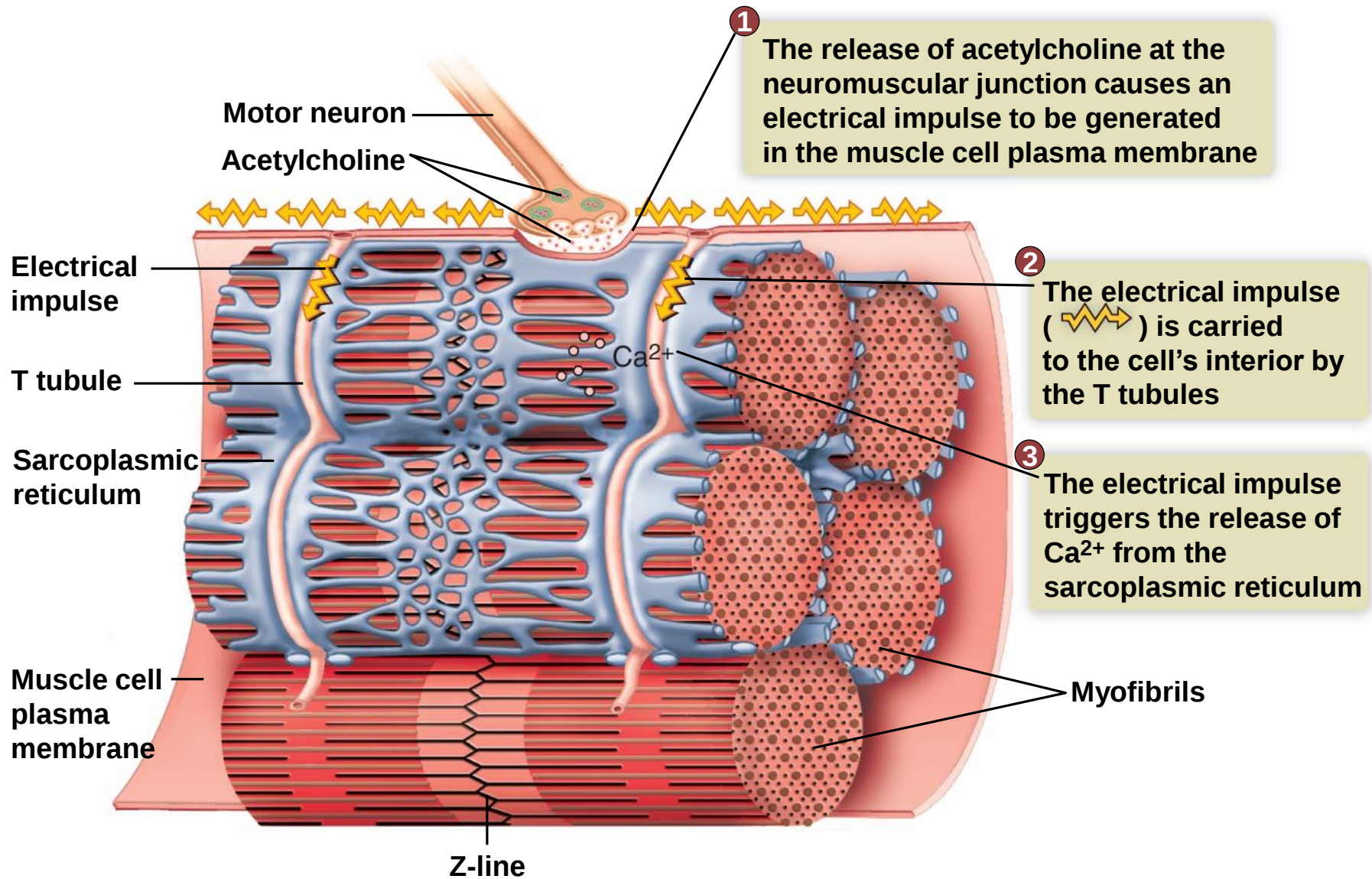
d) An electron micrograph cross section of a sarcomere in a region that contains both actin and myosin.



c) A transmission electron micrograph ($\times 11,300$) of a longitudinal section of a sarcomere. The rounded red objects are mitochondria.

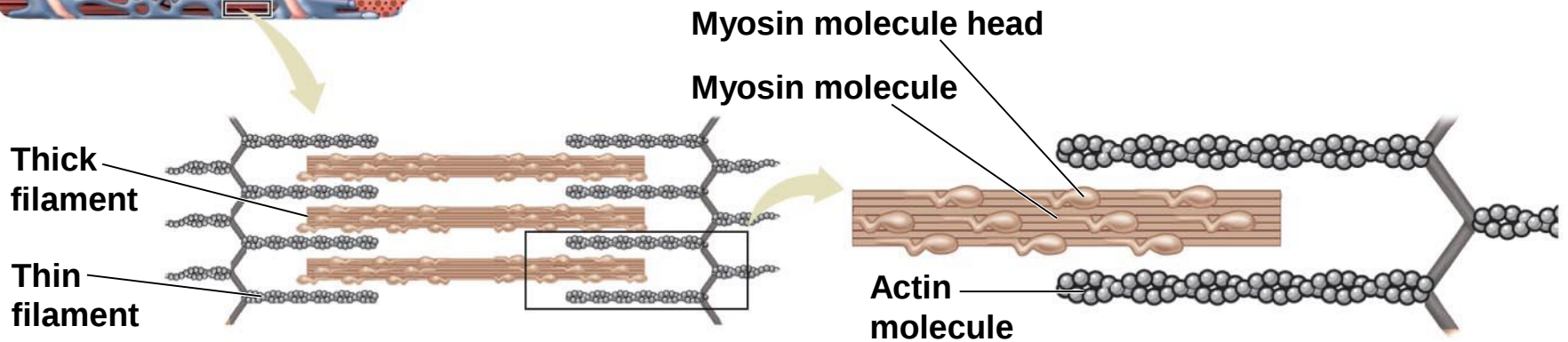
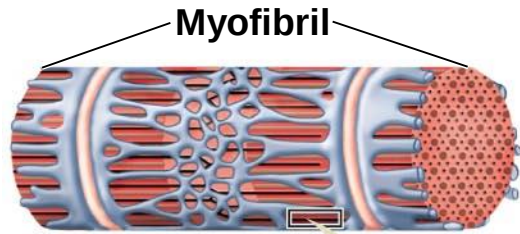
Nerve Activation of Individual Muscle Cells

- Acetylcholine is released from motor neuron at neuromuscular junction
- Electrical impulse transmitted along T tubules
- Calcium released from sarcoplasmic reticulum

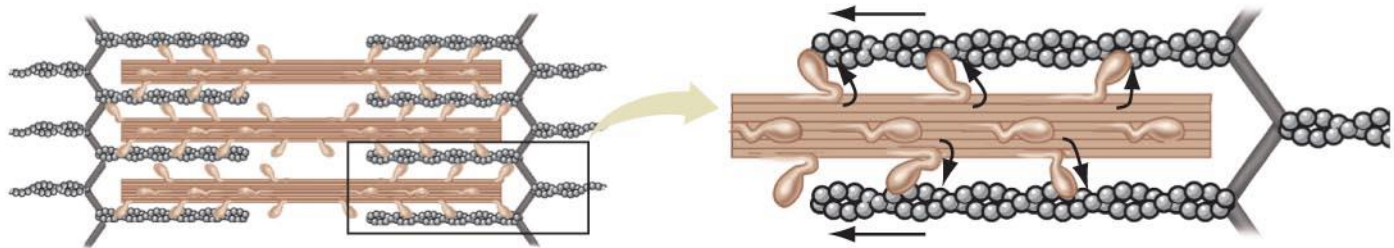


Calcium Initiates the Sliding Filament Mechanism

- Thick filaments
 - myosin
- Thin filaments
 - strands of actin molecules
- Contraction
 - formation of cross-bridges between thin and thick filaments



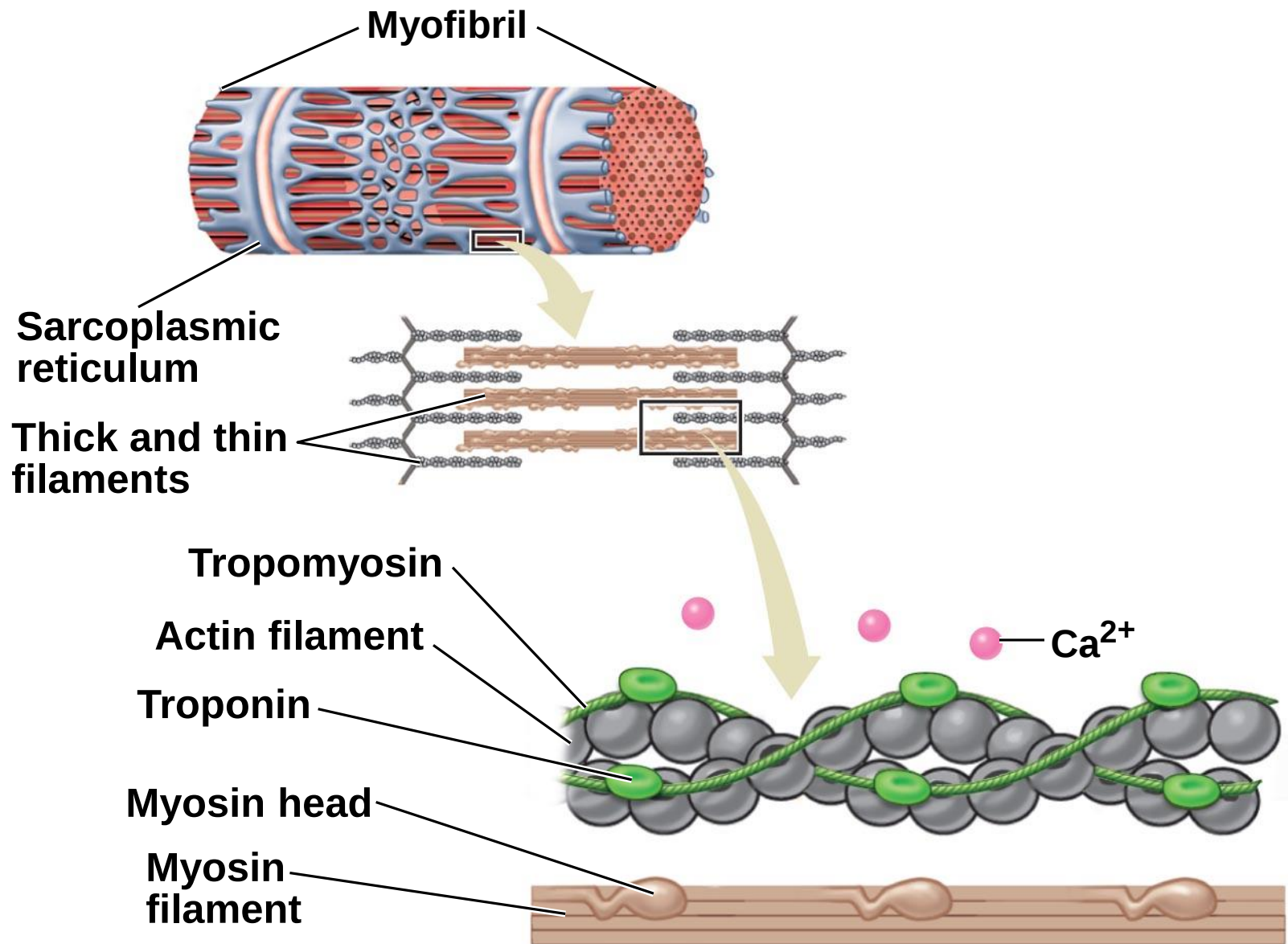
a) Relaxed state. The myosin heads do not make contact with actin.



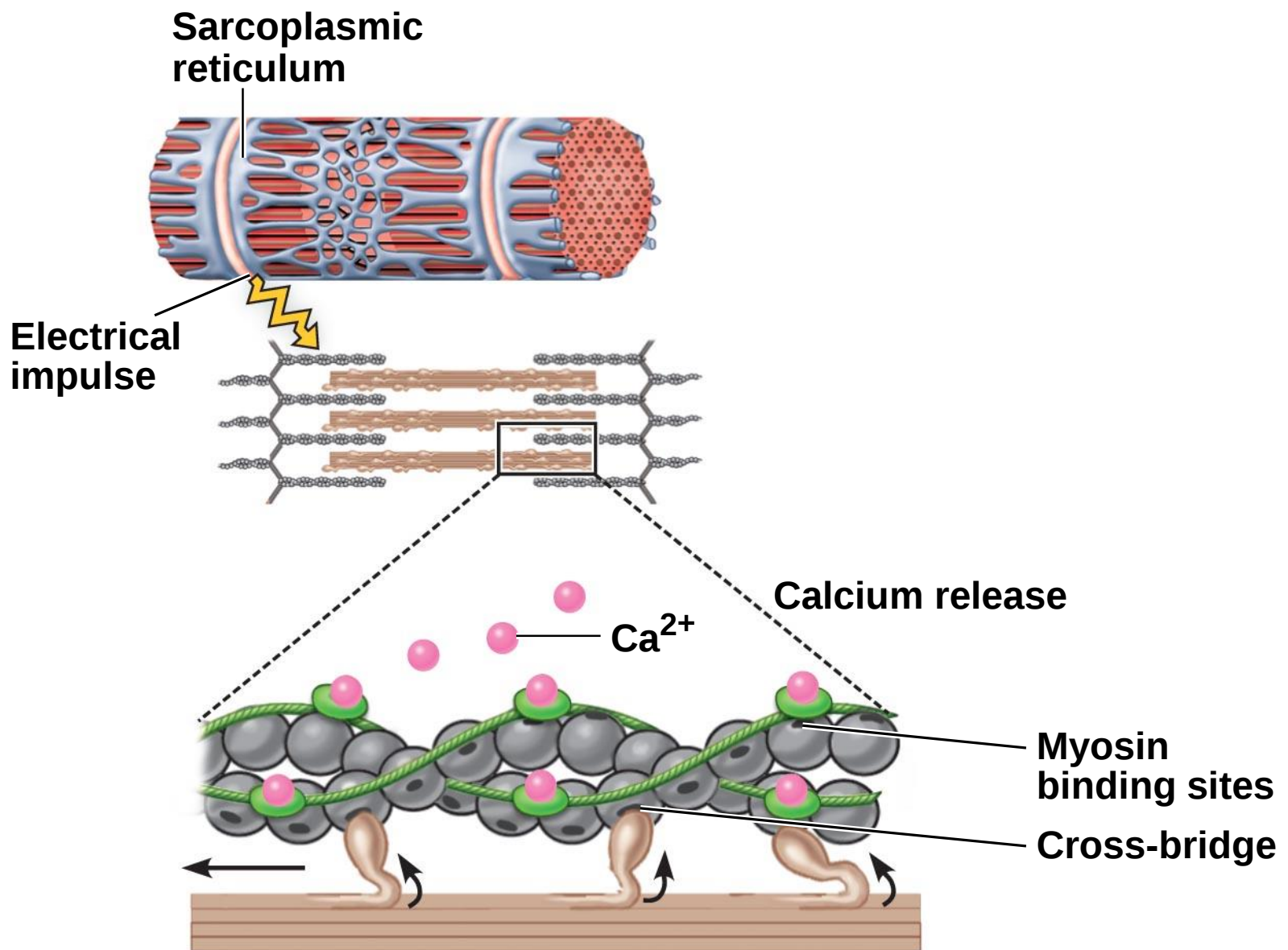
b) Contraction. The myosin heads form cross-bridges with actin and then bend, pulling the actin filaments toward the center of the sarcomere.

Mechanism of Muscle Contraction

- Calcium is released from sarcoplasmic reticulum
- Calcium binds to troponin
- Troponin–tropomyosin complex shifts position
- Myosin binding site is exposed
- Myosin heads form cross-bridges with actin
- Actin filaments are pulled toward center of sarcomere



a) Resting sarcomere. In the absence of calcium the muscle is relaxed because the myosin heads cannot form cross-bridges with actin.



b) Cross-bridge attachment. The binding of calcium to troponin causes a shift in the troponin-tropomyosin complex, allowing cross-bridges to form.

Muscle Relaxation

- Nerve activation ends, contraction ends
- Calcium pumped back into sarcoplasmic reticulum
- Calcium removed from troponin
- Myosin binding site covered
- No calcium = no cross-bridges

Energy Required for Muscle Activity

- Principle source of energy
 - ATP
- ATP required for contraction
- ATP required for relaxation
- ATP is replenished by a variety of means
 - Creatine phosphate
 - Stored glycogen
 - Aerobic metabolism of glucose, fatty acids, and other high-energy molecules

Activity of Muscles Can Vary

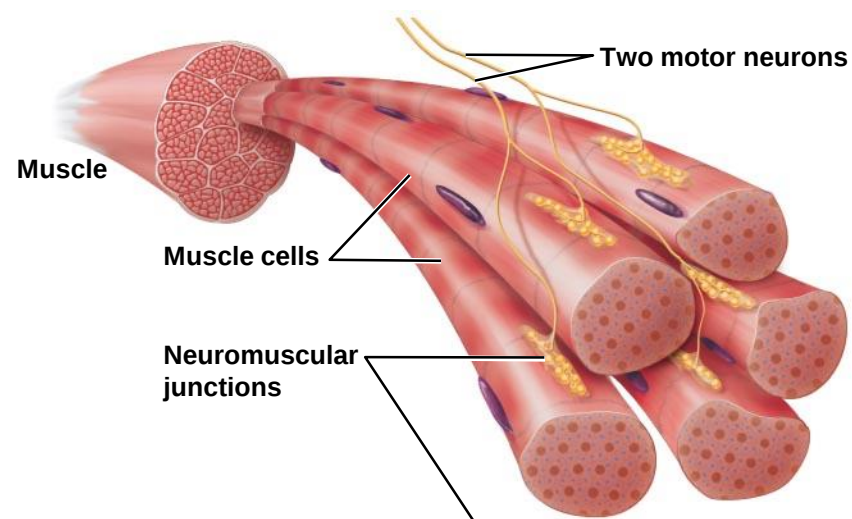
- **Isotonic contractions**
 - muscle shortens, movement occurs
- **Isometric contractions**
 - muscle doesn't shorten, no movement
- Degree of nerve activation influences force

Degree of Nerve Activation Influences Force

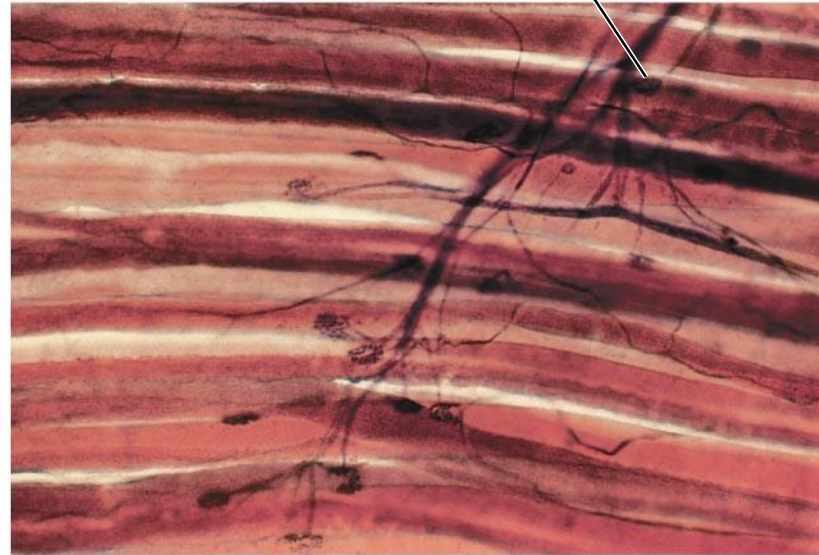
- **Motor unit**
 - Motor neuron and all the muscle cells it controls
 - Smallest functional unit of muscle contraction
- **Muscle tension**
 - Mechanical force that muscles generate when they contract
 - Determined by
 - Motor unit size
 - Number of active motor units
 - Frequency of stimulation of motor units

Degree of Nerve Activation Influences Force

- **All-or-none principle**
 - Individual muscle cells are completely contracting or are relaxed
- **Muscle tone**
 - Whole muscles – maintain intermediate level of force known as muscle tone
- **Recruitment**
 - Activation of additional motor units increases muscle tone



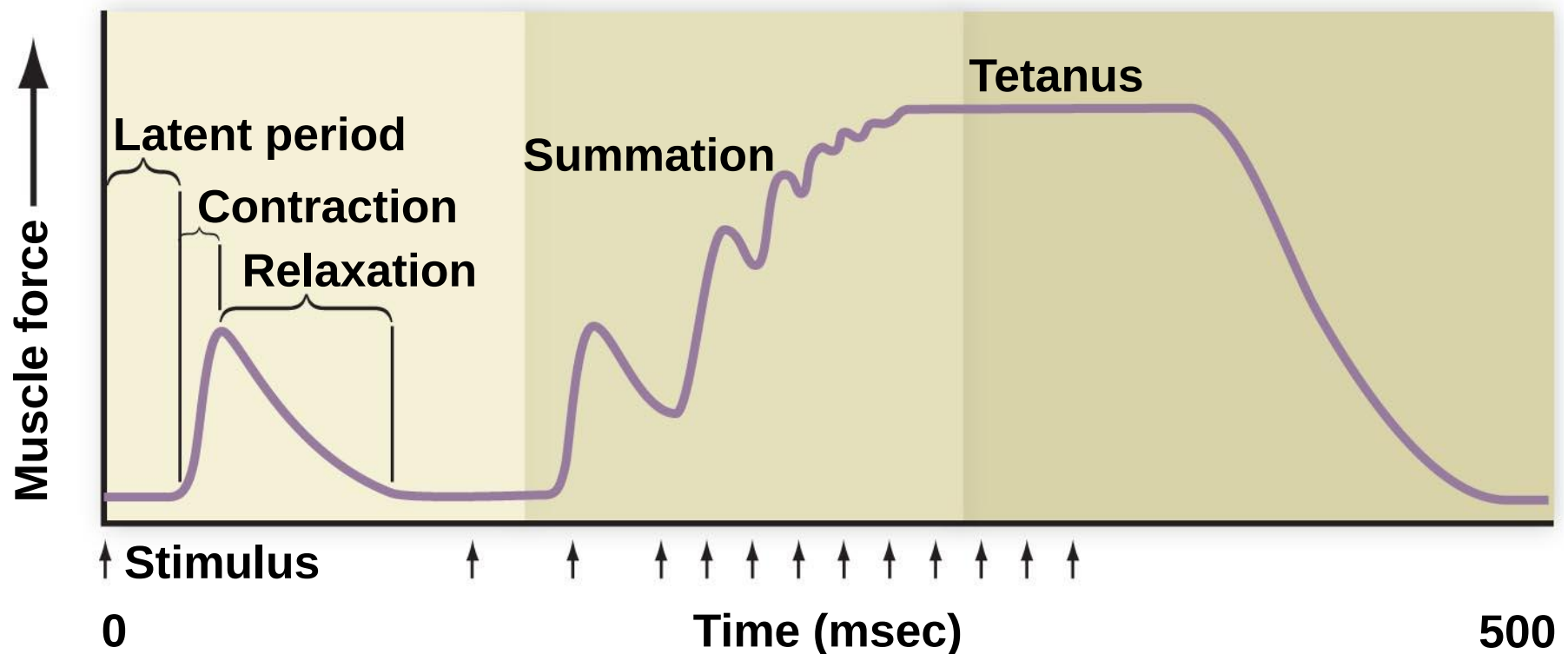
a) A motor unit consists of a motor neuron and all of the muscle cells it controls. Any one muscle cell is controlled by only one motor neuron, but a motor neuron controls more than one muscle cell.



b) Photograph of the muscle cells in a motor unit, showing branches of the motor neuron and neuromuscular junctions.

Muscle Twitch

- Complete cycle of contraction-relaxation in response to stimulus
- Can be observed using a myogram (laboratory recording of muscle activity)



Muscle Activity

- Two types of muscle fibers
 - **Slow twitch**
 - endurance, long duration contraction, contain myoglobin
 - Jogging, swimming, biking
 - **Fast twitch**
 - strength, white muscle, short duration contraction
 - Sprinting, weight lifting, tennis

Exercise Training

- **Strength training**
 - Resistance training
 - Short, intense
 - Builds more fast-twitch myofibrils
- **Aerobic training**
 - Builds endurance
 - Increases blood supply to muscle cells
 - Reach target heart rate for at least 20 minutes, three times a week

Diseases and Disorders of the Muscular System

- Muscular dystrophy
 - Hereditary diseases
 - Missing gene that produces protein (*dystrophin*)
- Tetanus
 - Bacterial infection
 - Causes muscles to 'lock up'

Diseases and Disorders of the Muscular System

- Muscle cramps
 - Uncontrolled flex of muscle
 - Caused by:
 - Dehydration & Ion imbalance
- Pulled muscles
 - Stretching the muscle too far
- Fasciitis
 - Inflammation of the connective tissue around muscles