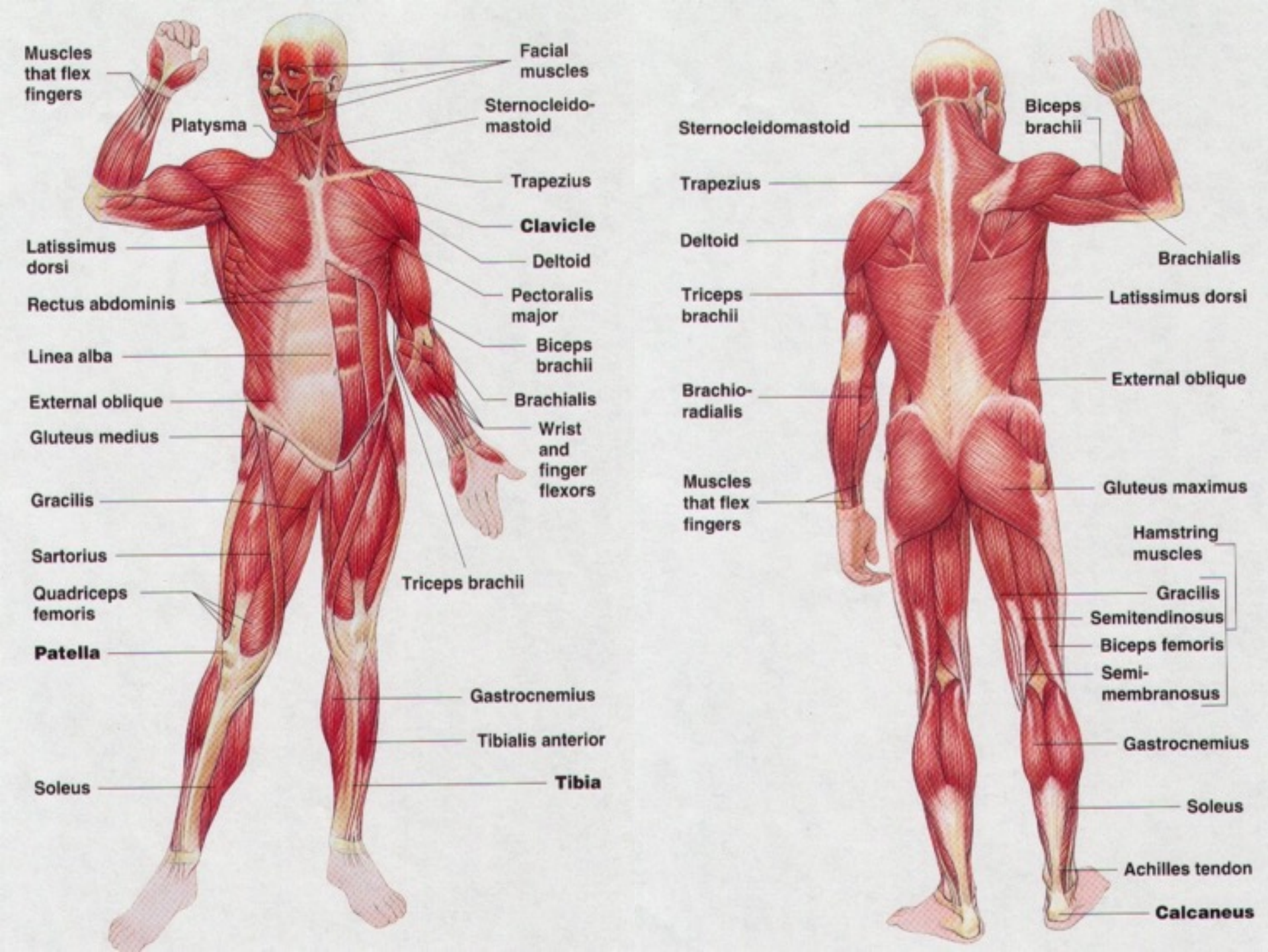
The Muscular System

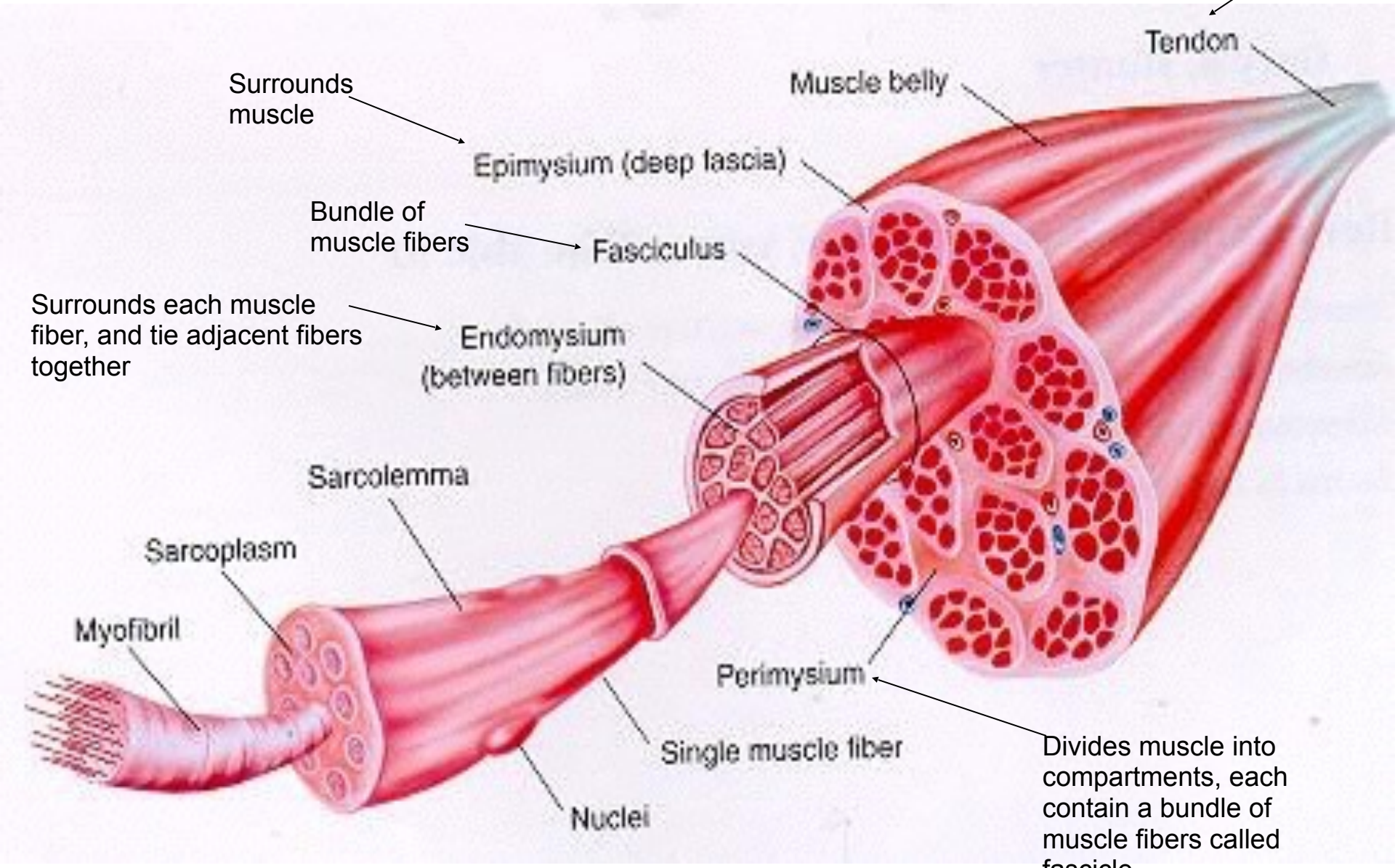
- What do skeletal muscles do?
- How do muscles work?


Muscles that flex fingers
Facial muscles
Platysma
Sternocleido-mastoid
Trapezius
Clavicle
Latissimus dorsi
Deltoid
Rectus abdominis
Pectoralis major
Linea alba
Biceps brachii
External oblique
Brachialis
Gluteus medius
Wrist and finger flexors
Gracilis
Sartorius
Triceps brachii
Quadriceps femoris
Patella
Gastrocnemius
Tibialis anterior
Soleus
Tibia
Sternocleidomastoid
Biceps brachii
Trapezius
Deltoid
Brachialis
Triceps brachii
Latissimus dorsi
External oblique
Brachio-radialis
Muscles that flex fingers
Gluteus maximus
Hamstring muscles
Gracilis
Semitendinosus
Biceps femoris
Semi-membranosus
Gastrocnemius
Soleus
Achilles tendon
Calcaneus

A. Function of Skeletal Muscles

- Produce movement
  - Muscle pulls tendons to move the skeleton
- Maintain posture and body position
  - Continuous muscle contraction
- Support soft tissue
  - Support weight of visceral organs
- Guard entrances and exits
  - Encircle openings to digestive and urinary tracts. Control swallowing, defecation and urination
- Maintain body temperature
  - Energy from contraction is converted to heat

B. Anatomy of Skeletal Muscles - Gross Anatomy



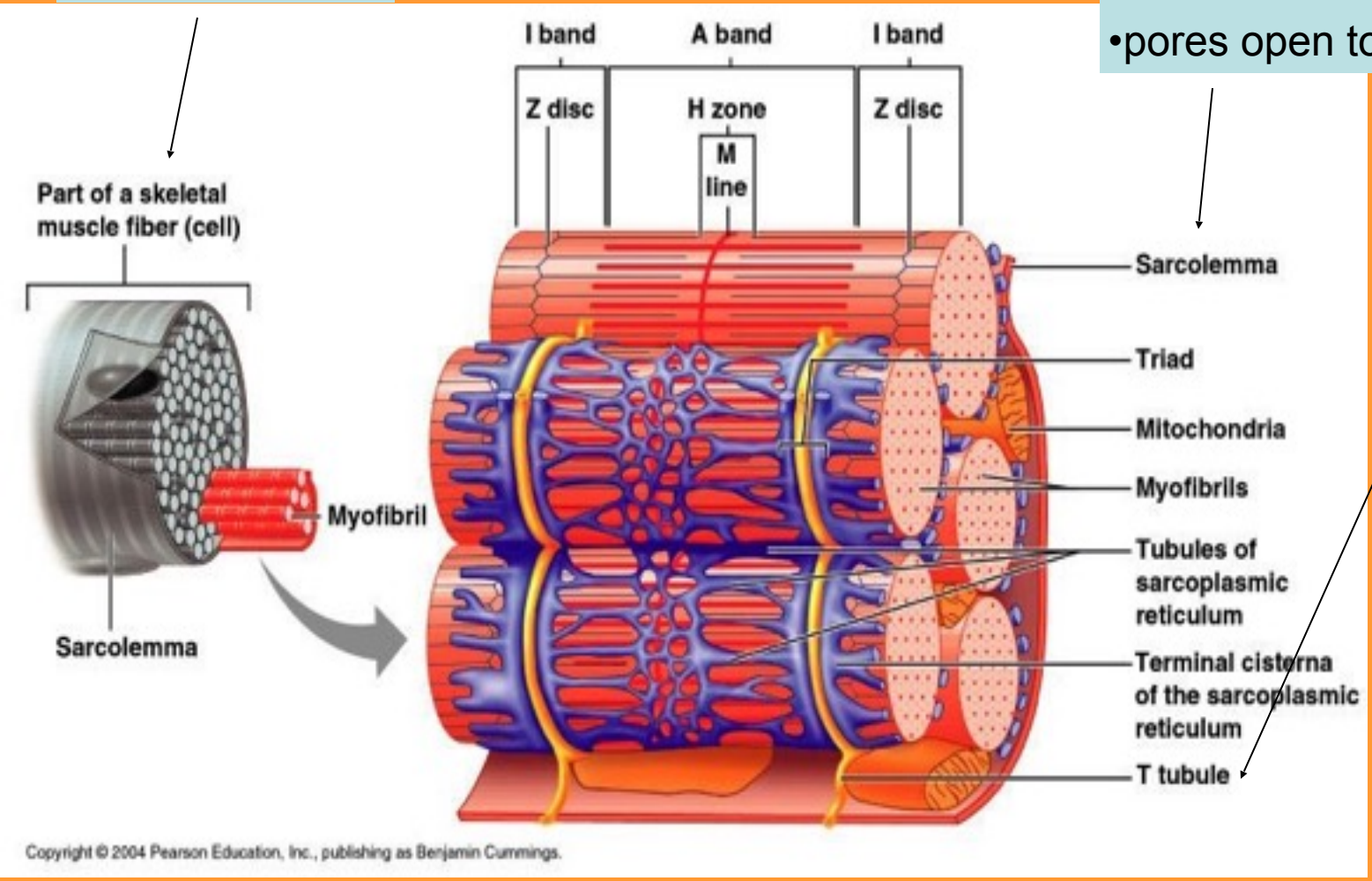
B. Anatomy of a Skeletal Muscle – Blood Vessels and Nerves

- Muscle contractions require energy
  - Blood vessels deliver oxygen and nutrients to produce ATP
- Muscle contractions are under stimulation from the CNS
  - Voluntary control
  - Axons connect to individual muscle fibers

Microanatomy – Sarcolemma and T-Tubules

- Very large cells
- 100's of nuclei

- Cell membrane
- pores open to T-tubules



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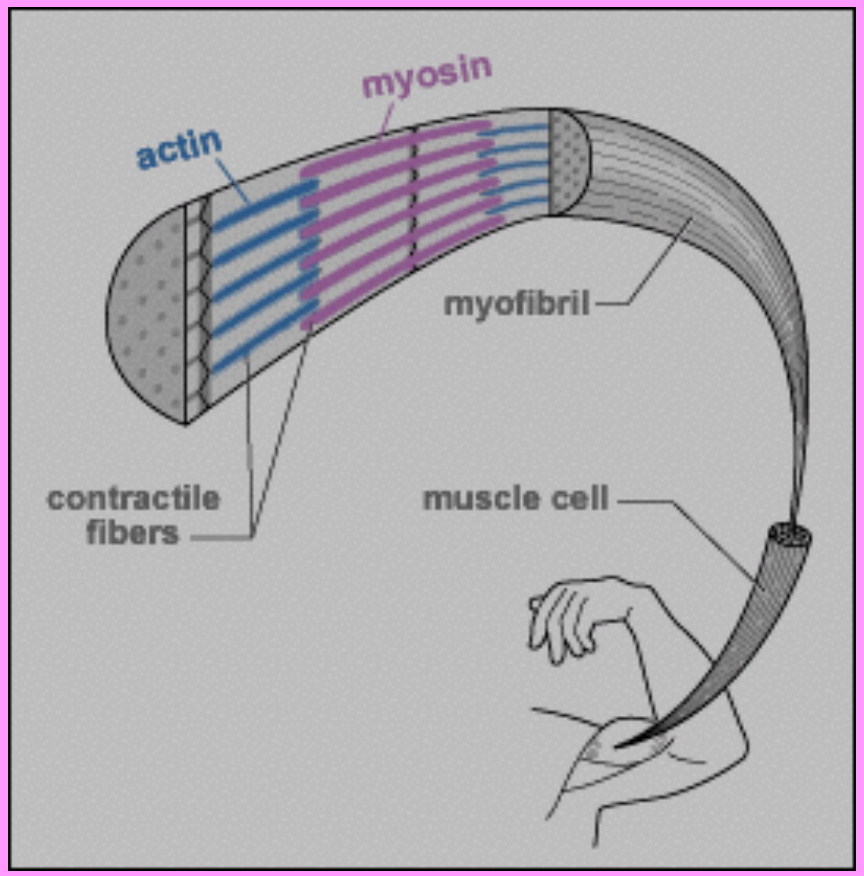
- Network of narrow tubules
- filled with extracellular fluid
- form passageways through muscle fiber

Myofibrils

- Cylinder as long as entire muscle fiber
- Each fiber contains 100s to 1000s
- Responsible for contraction
- When myofibrils contract the whole cell contracts
- Consist of proteins
  - Actin – thin filaments
  - Myosin – thick filaments



Sarcoplasmic Reticulum

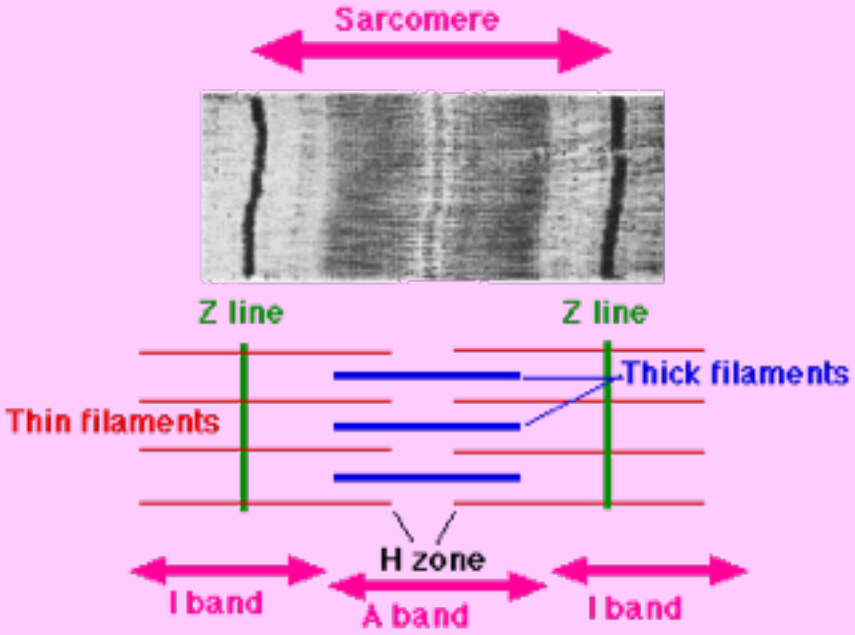
- Specialized form of SER
- Tubular network around each myofibril

- In contact with T-Tubule

- Cisternae – expanded chambers of SR, store Calcium

Sarcomere

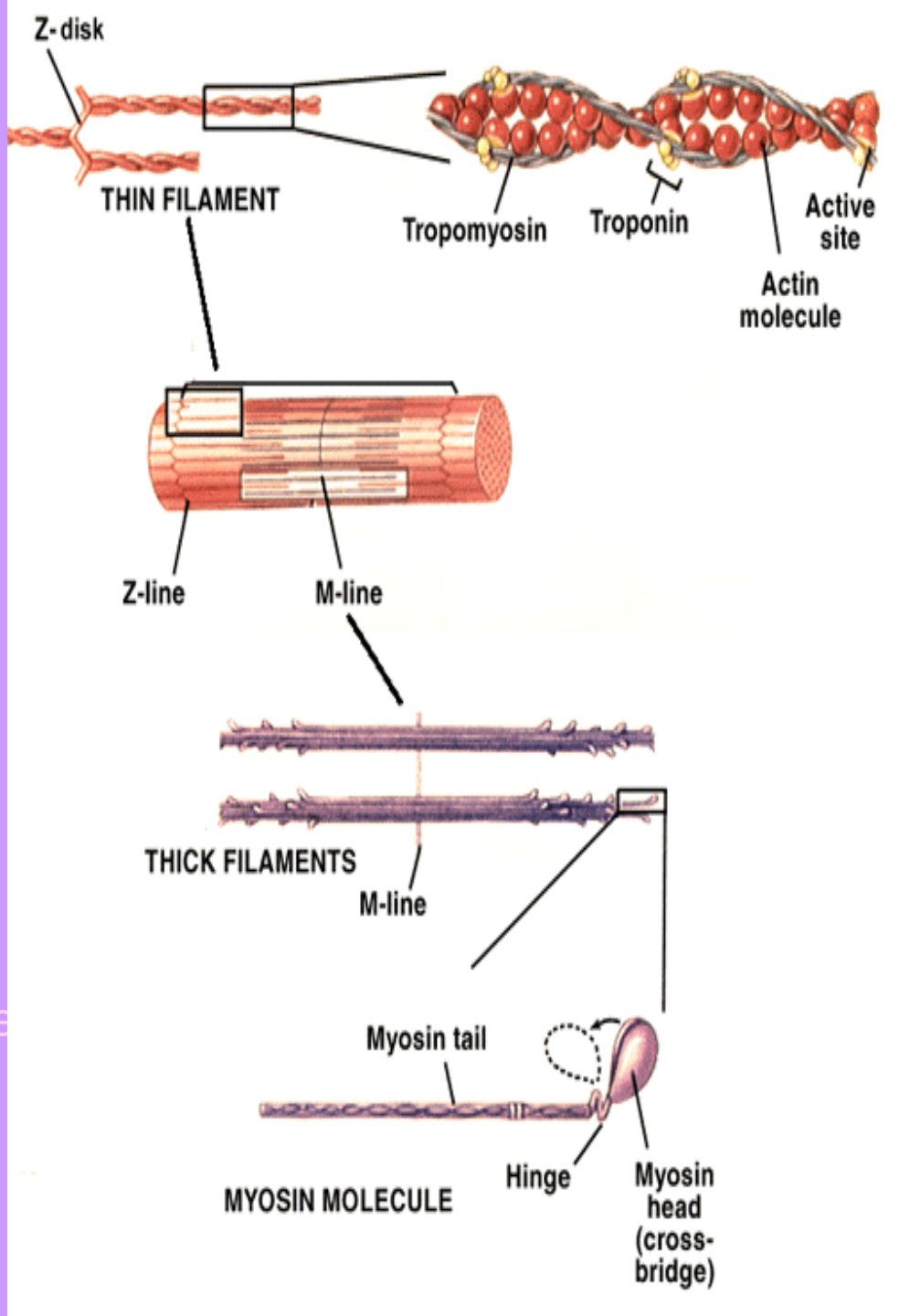
- Smallest functional unit of muscle fiber
- Each myofibril contains 10,000 sarcomeres end to end
- Interaction between thick and thin filaments cause contraction
- Banded appearance



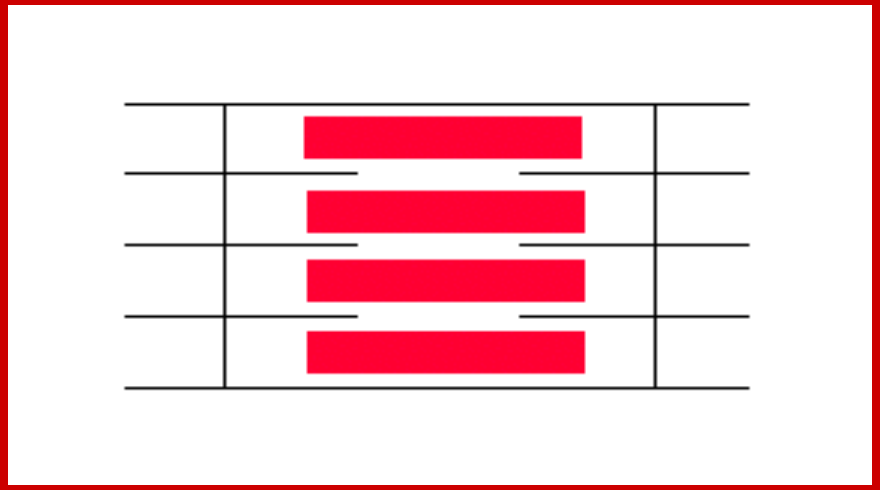
Thick and Thin Filaments

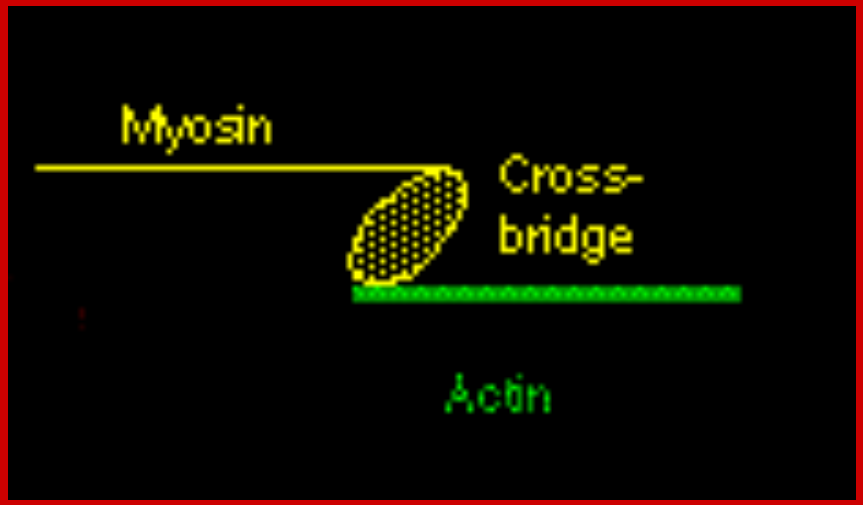
- Thin
  - twisted actin molecules
  - Each has an active site where they interact with myosin
  - Resting – active site covered by tropomyosin which is held in place by troponin

- Thick
  - Myosin
  - Head attaches to actin during contraction
  - Can only happen if troponin changes position, moving tropomyosin to expose active site



Sliding Filaments and Cross Bridges





- Sarcomere contraction – Sliding Filament Theory
  - Thin filaments slide toward center of sarcomere
  - Thick filaments are stationary
  - Myosin head attaches to active site on actin (cross bridge)
  - Pull actin towards center, then detaches

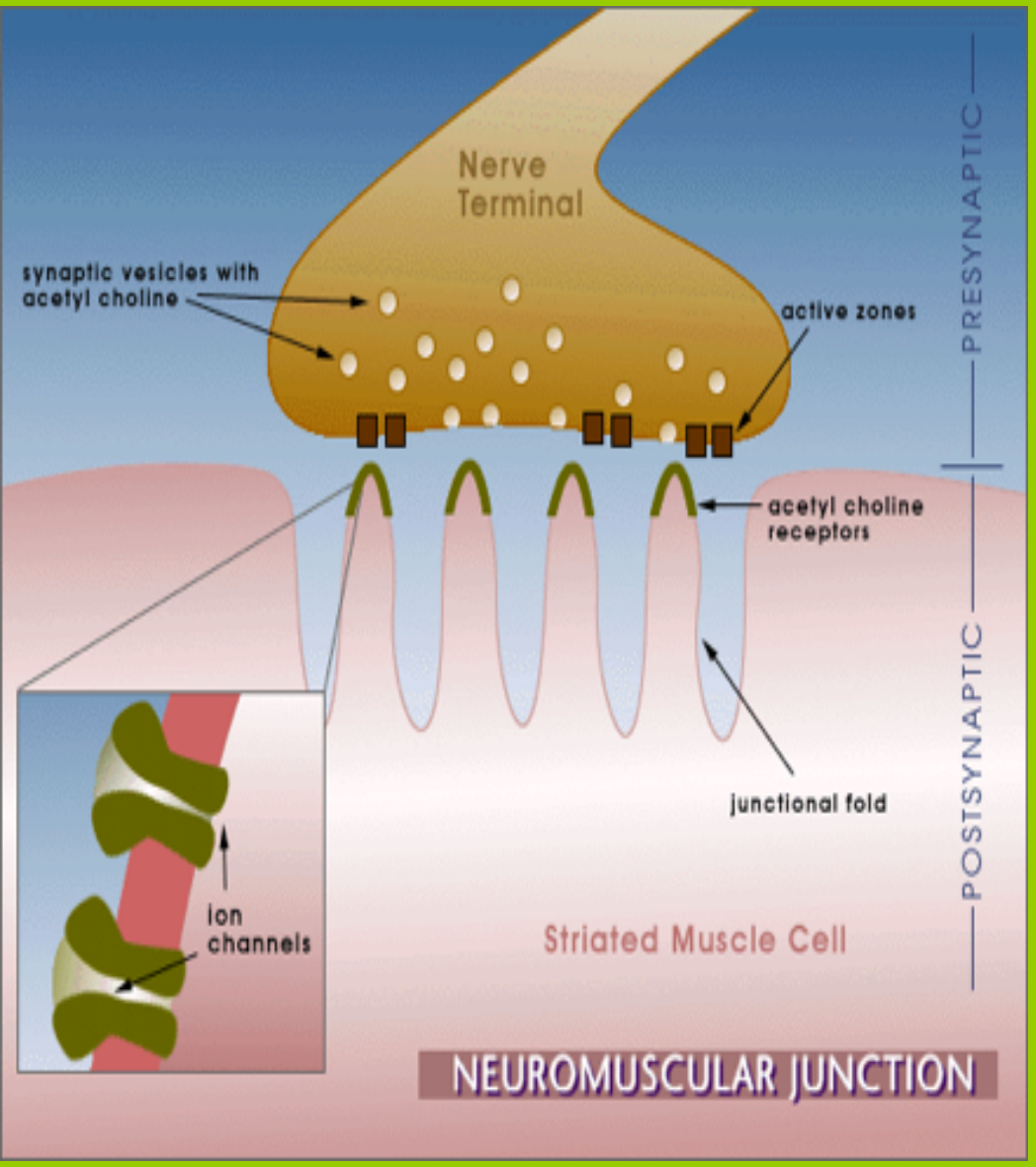
Questions

- How would severing the tendon attached to a muscle affect the ability of the muscle to move a body part?
- Why does skeletal muscle appear striated when viewed through a microscope?
- Where would you expect the greatest concentration of calcium ions in resting skeletal muscles to be?

Control of Muscle Fiber Contraction

Under control of the nervous system

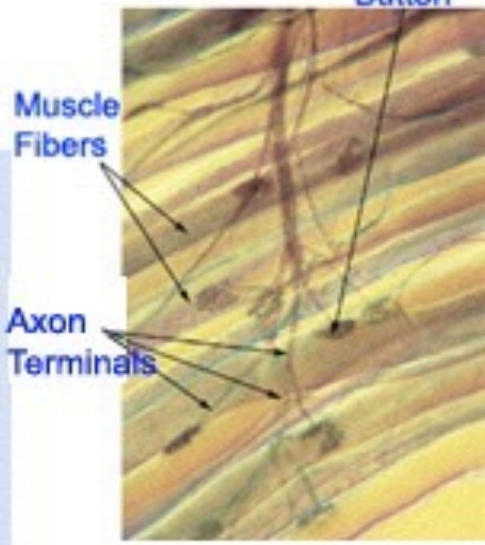
Neuromuscular Junction



- Link between NS and muscle
- Motor neuron – control skeletal muscle fibers
- Synaptic terminal
- Acetylcholine (Ach) – chemical released by neuron to communicate with other cells
  - Triggers change in sarcolemma which triggers contraction

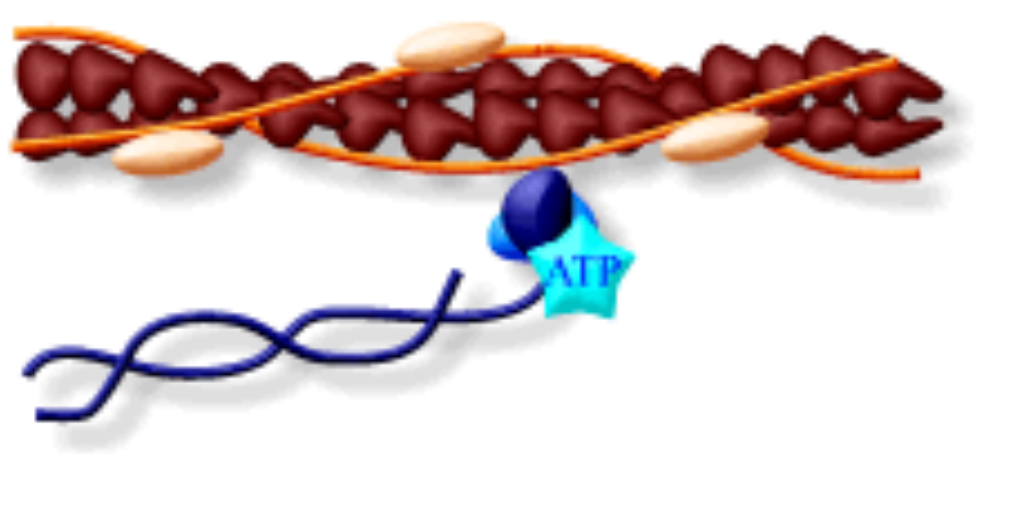
1. Action potential travels to axon of motor neuron
2. Ach is released into synaptic cleft
3. Ach diffuses across synaptic cleft & binds to Ach receptors on sarcolemma
    1. This changes permeability to sodium
    2. Sudden rush of sodium into sarcolemma
    3. Causes action potential sarcolemma
4. Action potential spreads over entire sarcolemma, down t-tubules to cisternae
5. Cisternae release massive amounts of calcium
6. Increase in calcium – sarcomeres contract
7. Ach broken down by AchE

The Neuromuscular Junction



Axon of motor neuron
Myelin sheath
Action potential
Axon terminal
Terminal button
Vesicle of acetylcholine
Voltage-gated Na^+ channel
Plasma membrane of muscle fiber
Acetylcholine receptor site
Acetylcholinesterase
Chemically gated cation channel
Ca^{2+}
Voltage-gated calcium channel
Action potential propagation in muscle fiber
Muscle fiber
K^+
Na^+
Motor end plate
1
2
3
4
5
6
7

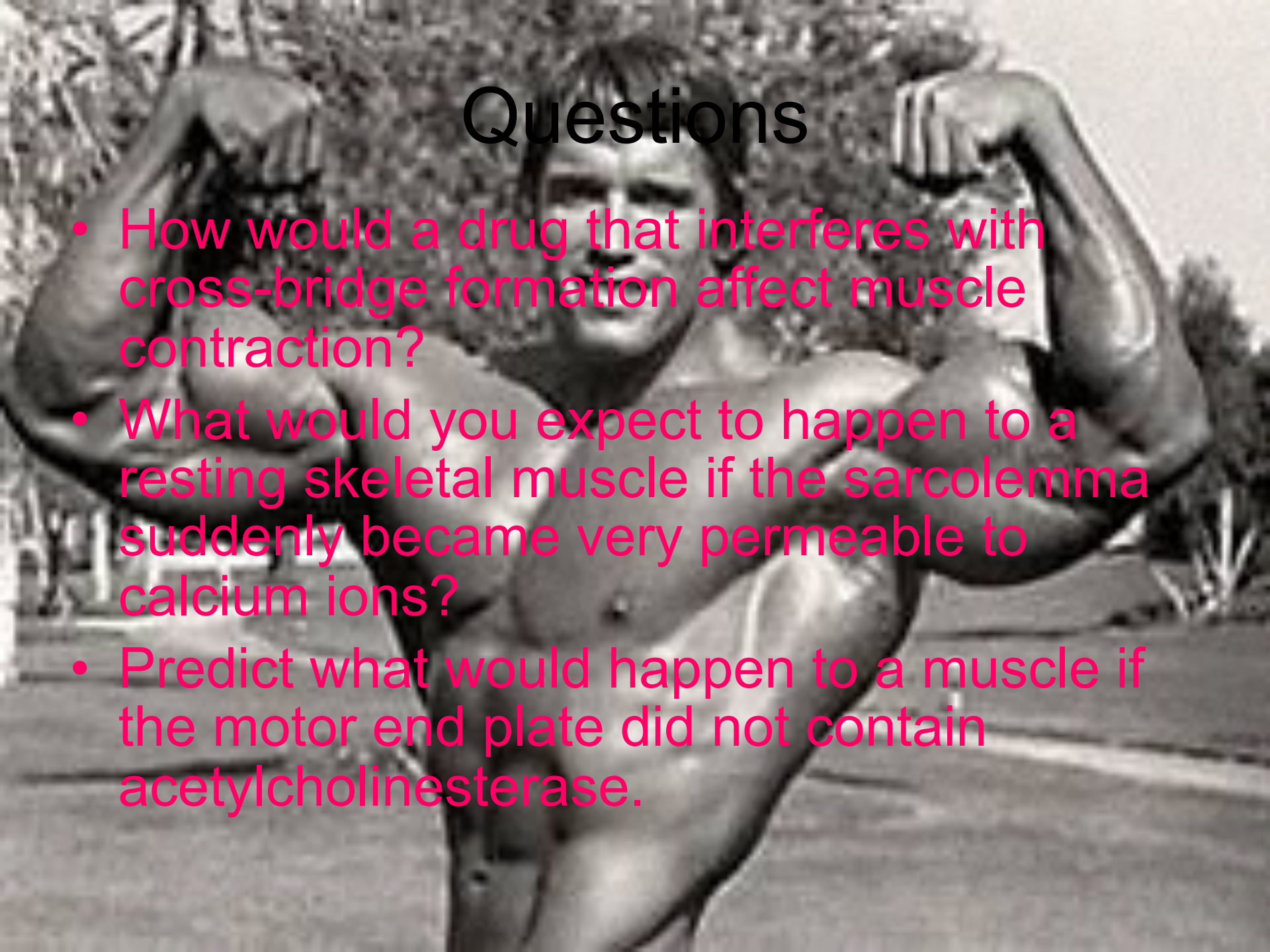
The Contraction Cycle



- Resting sarcomere
  - ADP + P attached to myosin head (stored energy)
- Step 1
  - Ca+ binds to troponin exposing active site on actin
- Step 2
  - Myosin head attaches to actin
- Step 3
  - Pulling of crossbridge towards center of sarcomere
  - ADP + P released (energy used)
- Step 4
  - Myosin head binds another ATP
  - Detachment of cross bridge
- Step 5
  - ATP → ADP + P, reactivation of myosin head

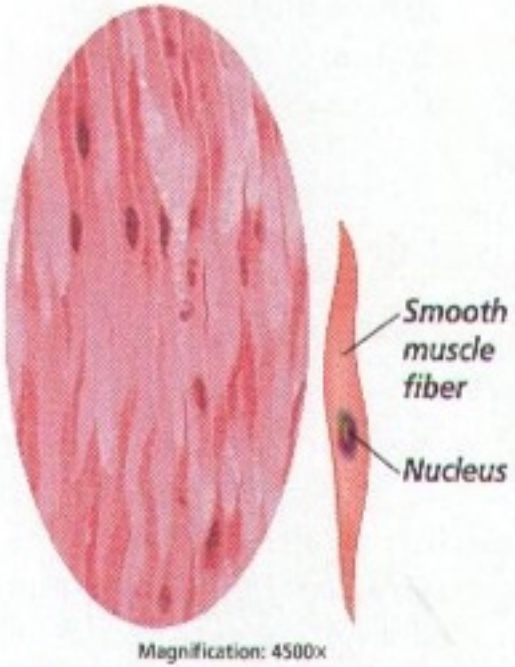
Summary of Muscle Contraction

1. Brain – spinal cord - motor nerve - neuromuscular junction
2. Acetylcholine(ACH) released by synaptic vesicles, crosses synaptic cleft
   -Acetylcholinesterase enzyme breaks down ACH, binds to receptors
3. Sodium ions "leak" into muscle cell initiating action potential which travels T-tubules to sarcoplasmic reticulum (SR)
4. Calcium ions (hifg affinity for troponin) released from SR
5. Calcium binds with troponin
6. Shift of tropomyosin, make sites available for myosin
7. With ATP present, ATPase splits ATP to ADP + P + Energy
8. Myosin combines with actin
9. Sliding action of actin over myosin (Sliding filament theory)
10. Impulse stops, calcium or ATP depleted, calcium ions pumped to SR
11. Tropomyosin returns over active sites on actin, myosin no longer bound



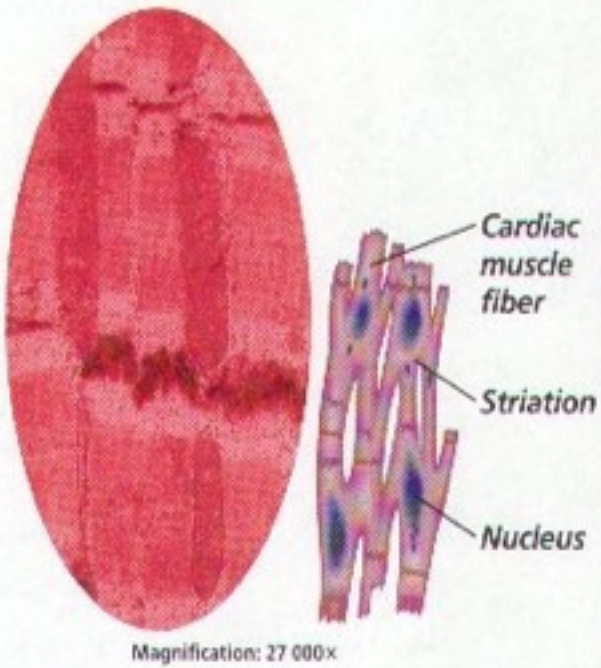
Questions

- How would a drug that interferes with cross-bridge formation affect muscle contraction?
- What would you expect to happen to a resting skeletal muscle if the sarcolemma suddenly became very permeable to calcium ions?
- Predict what would happen to a muscle if the motor end plate did not contain acetylcholinesterase.



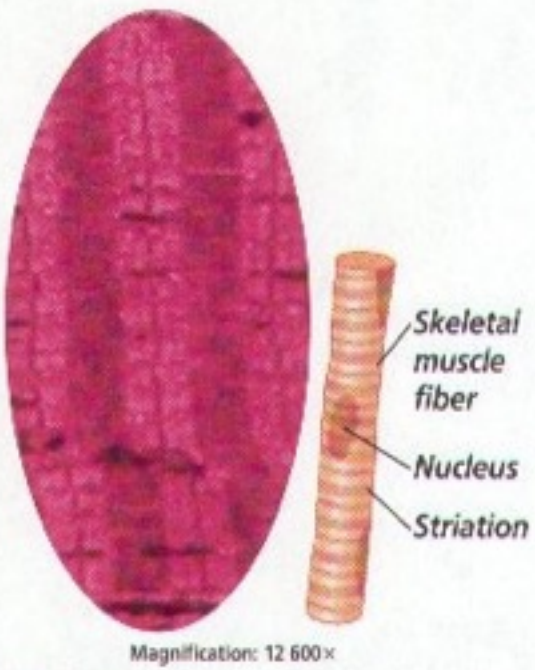
Magnification: 4500×

A Smooth muscle fibers are under involuntary control and appear spindle-shaped.



Magnification: 27 000×

B Cardiac muscle fibers, which are also under involuntary control, appear striated or striped when magnified.



Magnification: 12 600×

C Skeletal muscle fibers, while also striated, are under voluntary control.