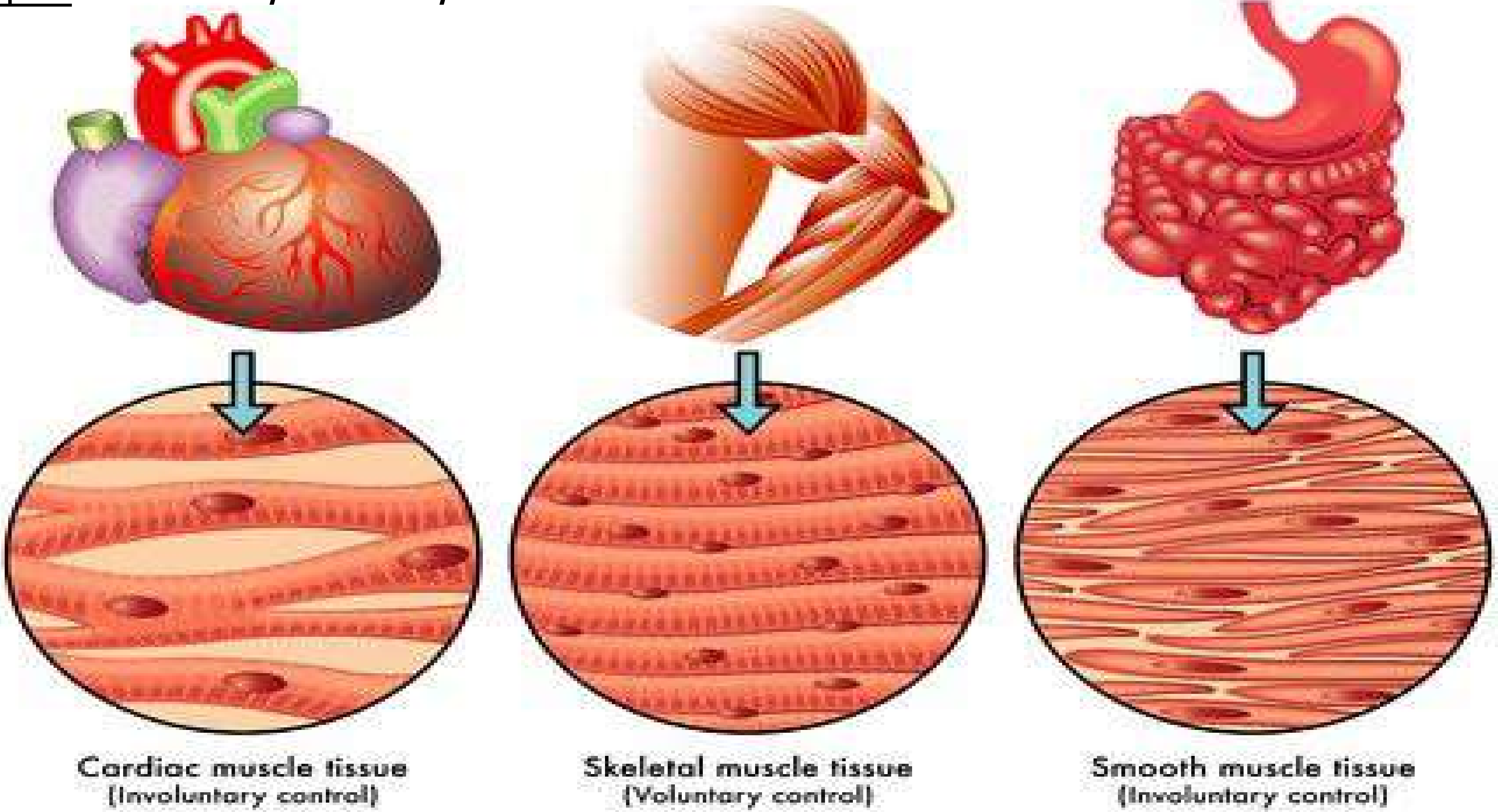
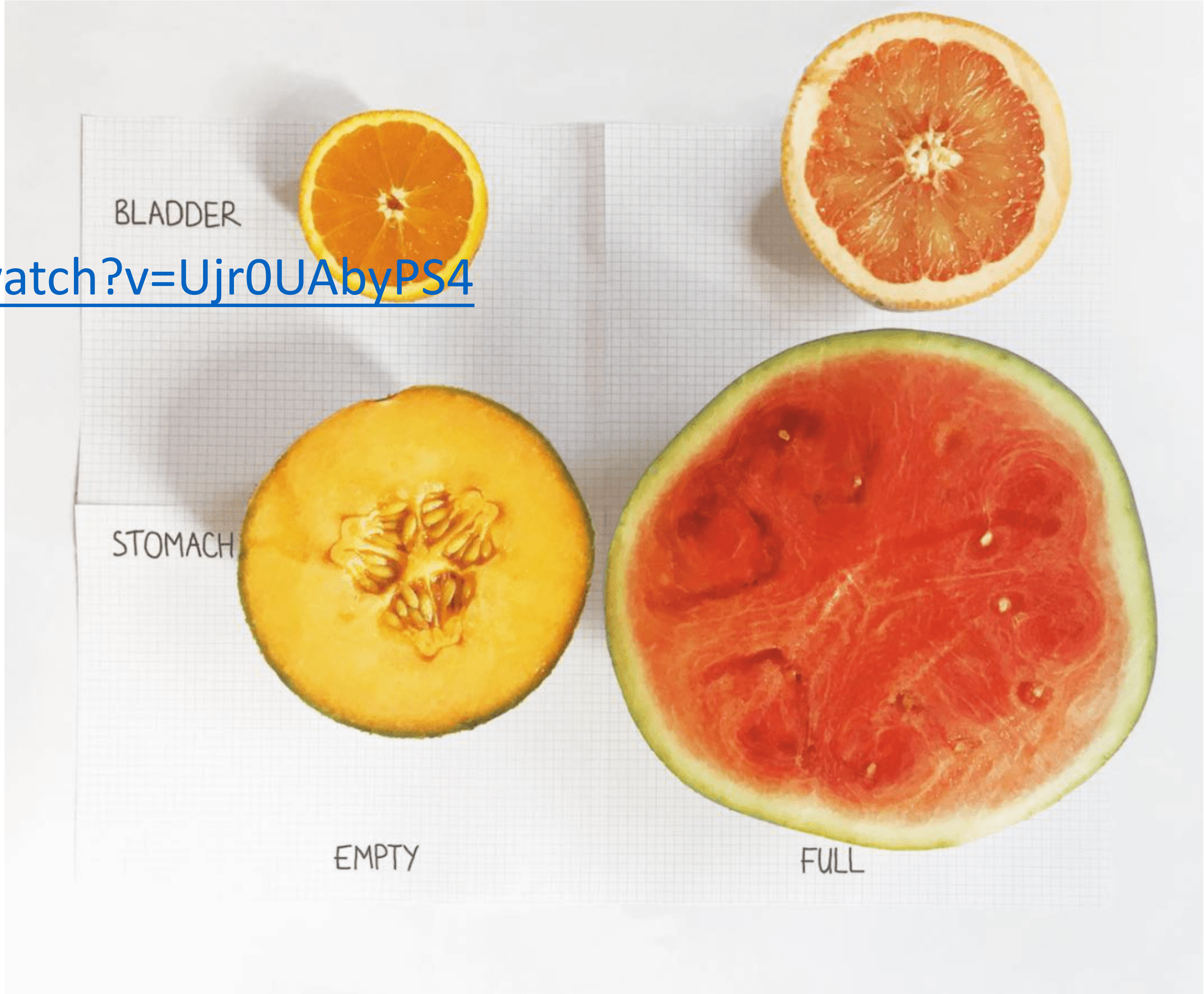
Muscle (myology - the study of muscle)

Types – Smooth, skeletal, cardiac



Functions –
Motion within
Regulate organ volume

https://www.youtube.com/watch?v=Ujr0UAbyPS4

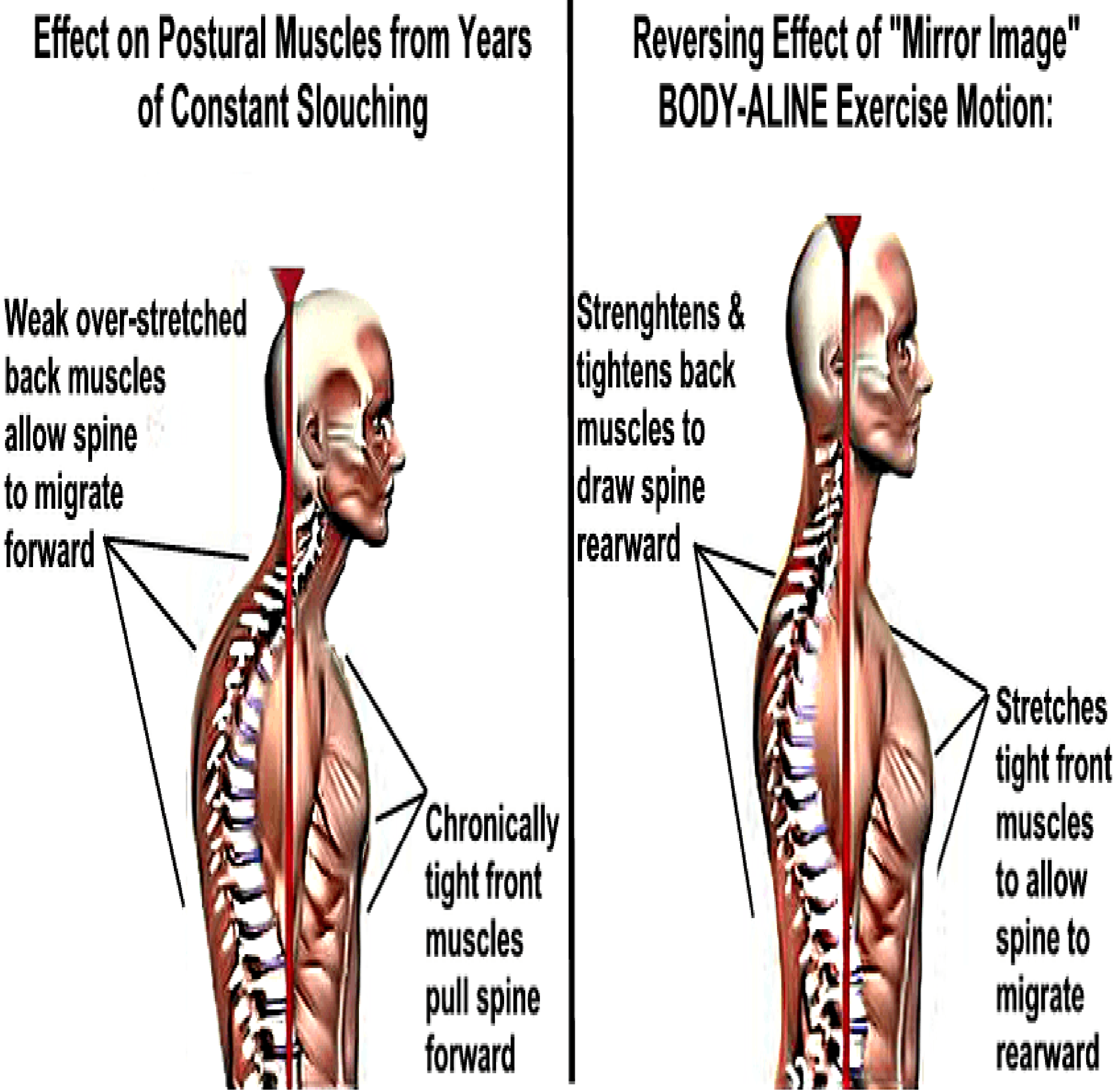


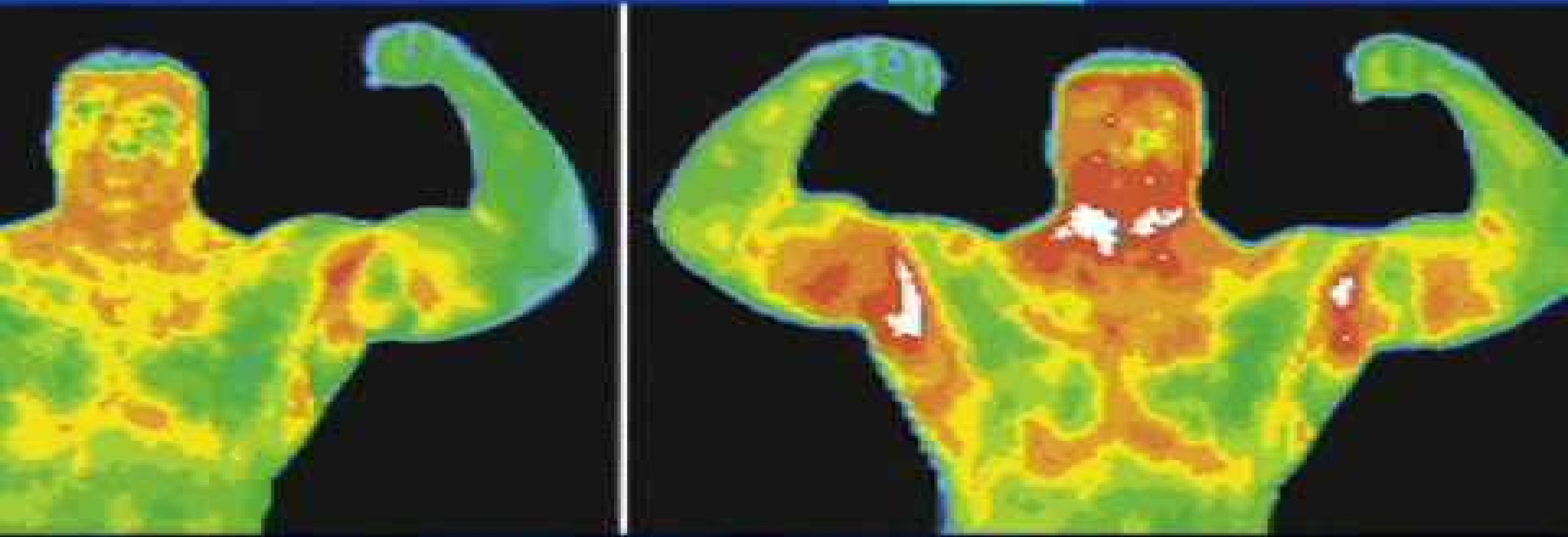
Movement

Stabilized position

Heat Production

https://www.youtube.com/watch?v=6ObNnCTV6MY



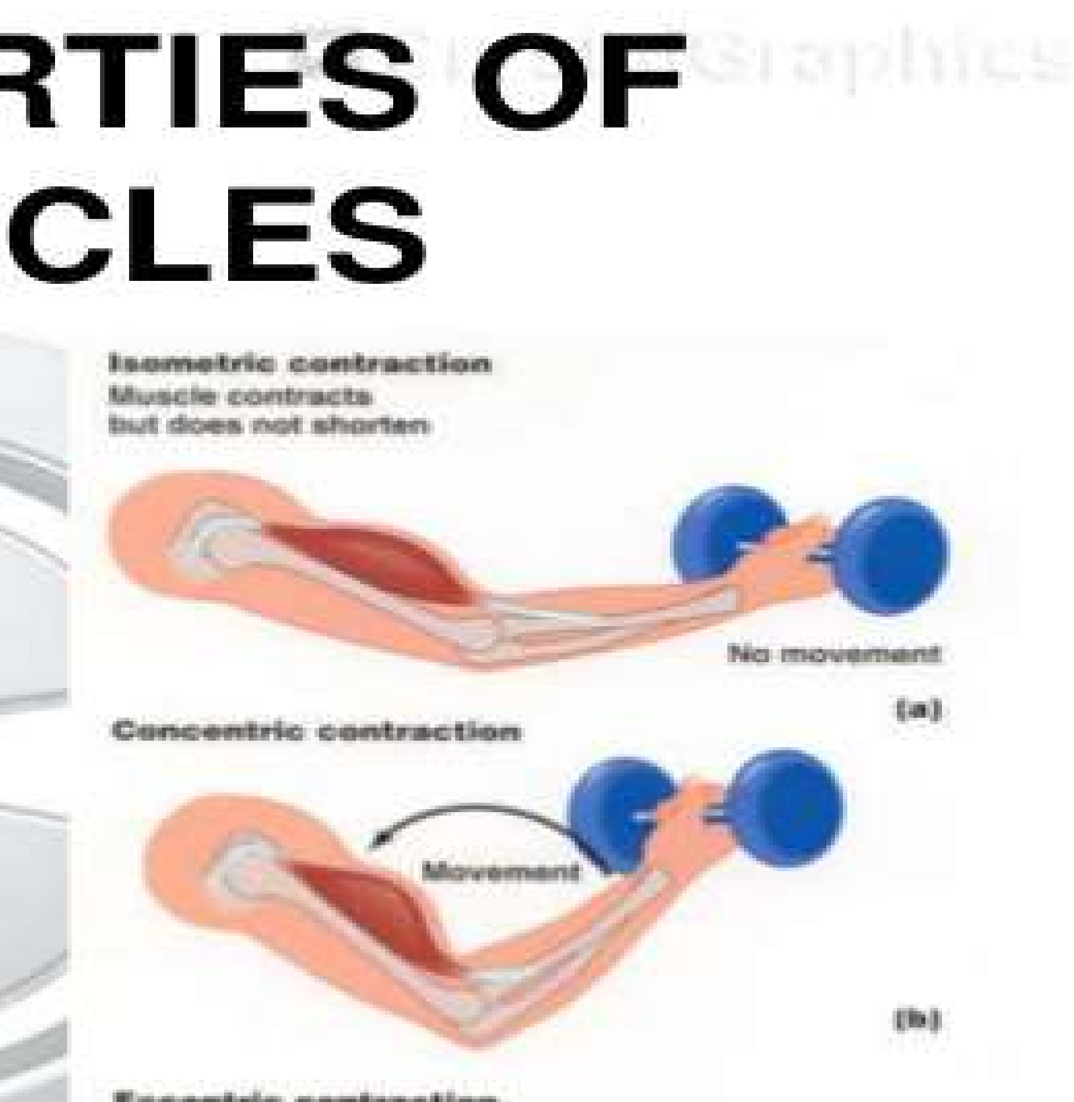


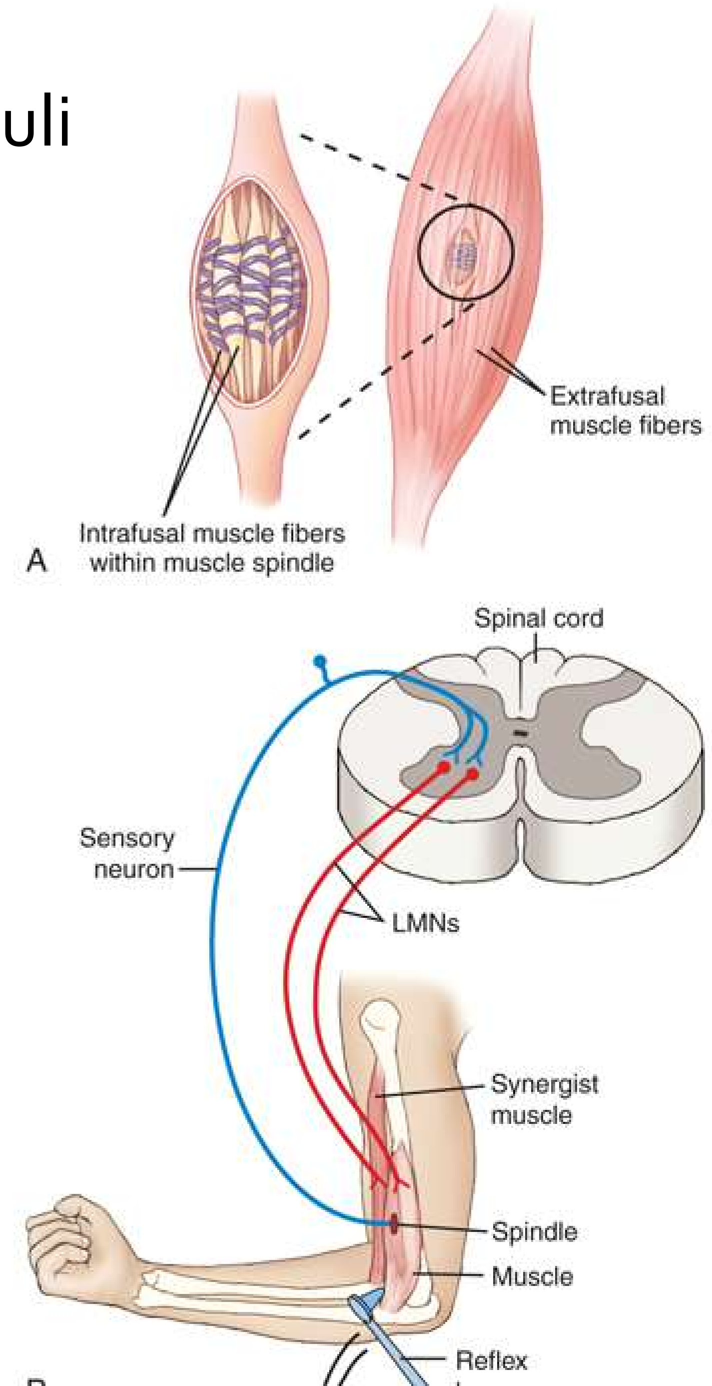
- advanced technology used in numerous medical fields
- detects and captures thermogenic heat production from the body
- highly accurate - reads and produces readings within 0.2F

Characteristics

Excitability - able to receive/respond to stimuli

Contractibility - the ability to shorten





Characteristics

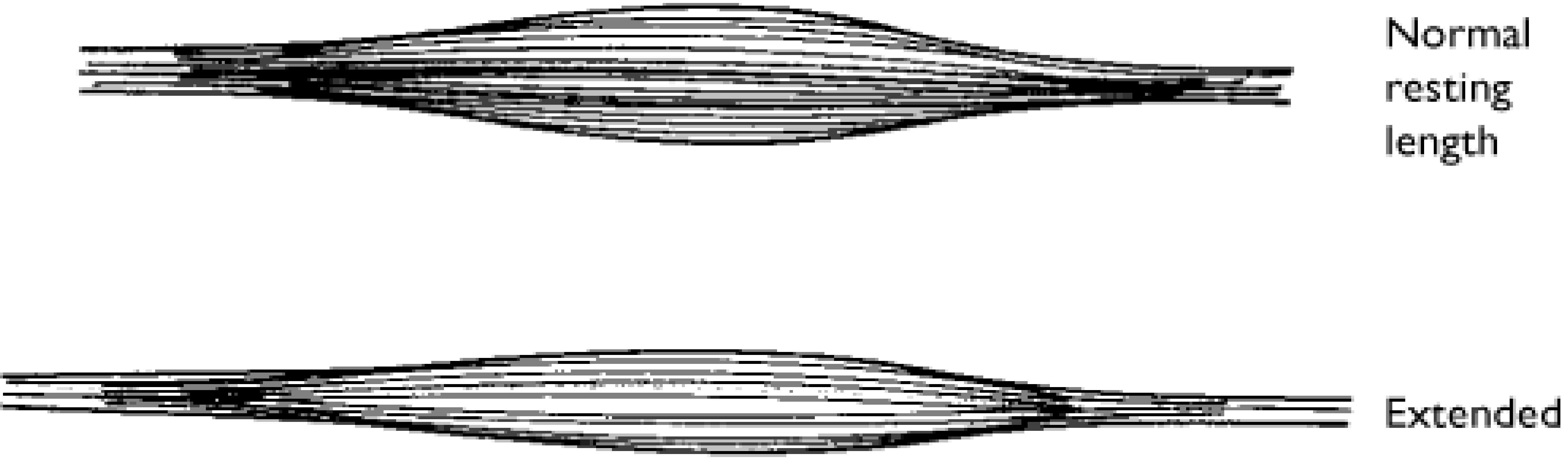
Excitability - able to receive/respond to stimuli

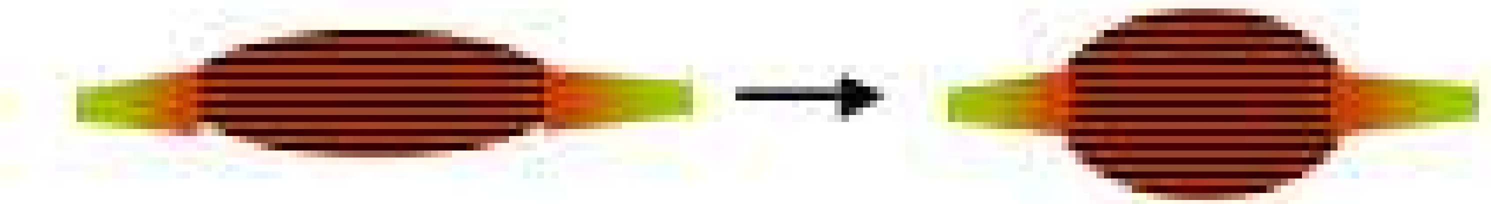
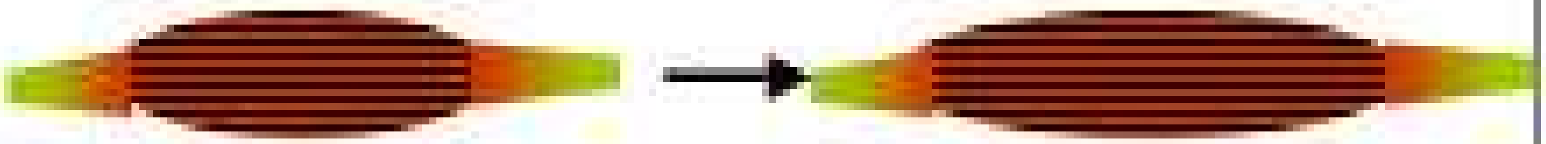
Contractibility - the ability to shorten

Extensibility - the ability to lengthen

Elasticity - the ability to return to original size

https://www.youtube.com/watch?v=pWAvmQZjdXk

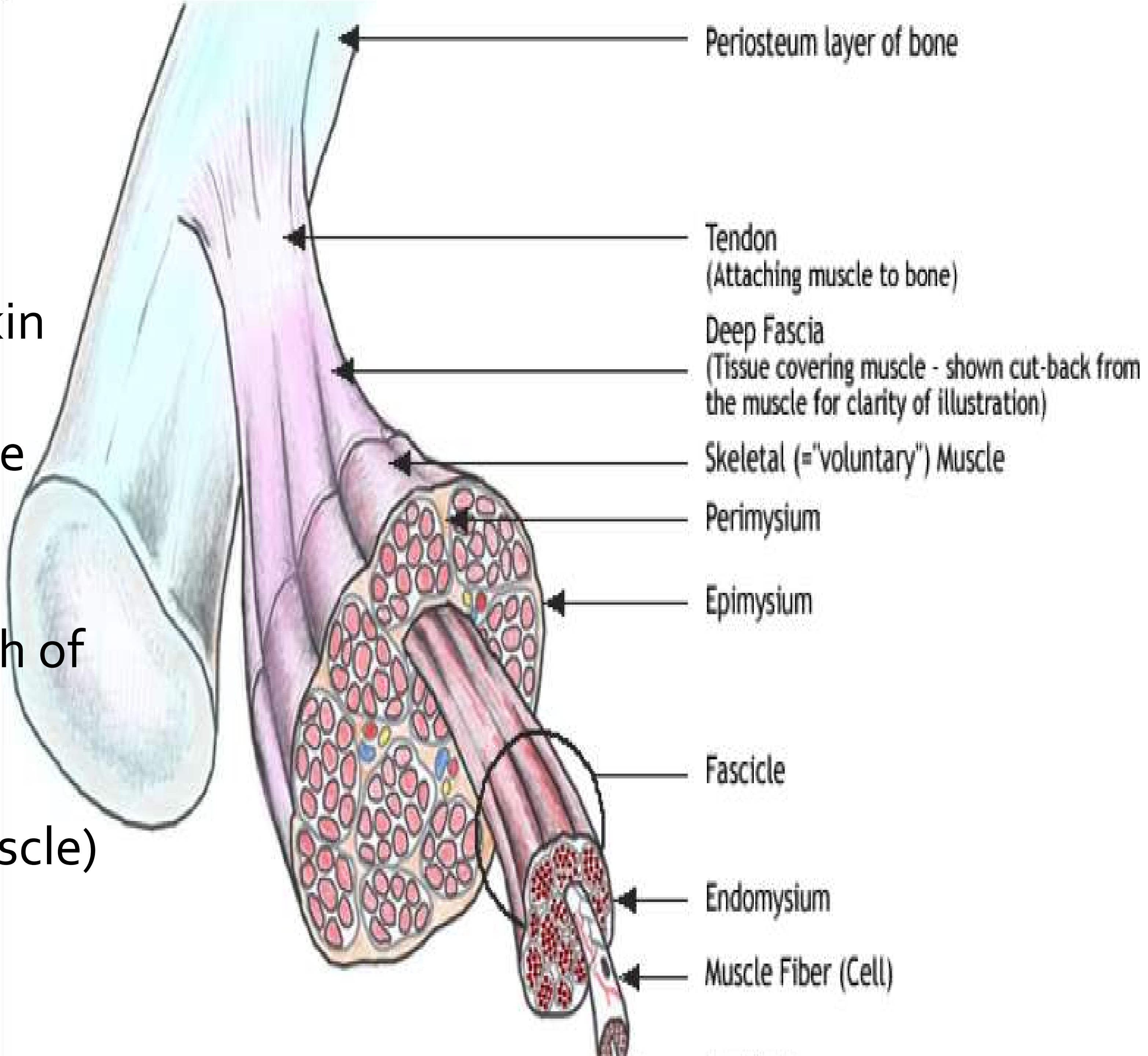


Contractility	
Excitability	
Extensibility	
Elasticity	

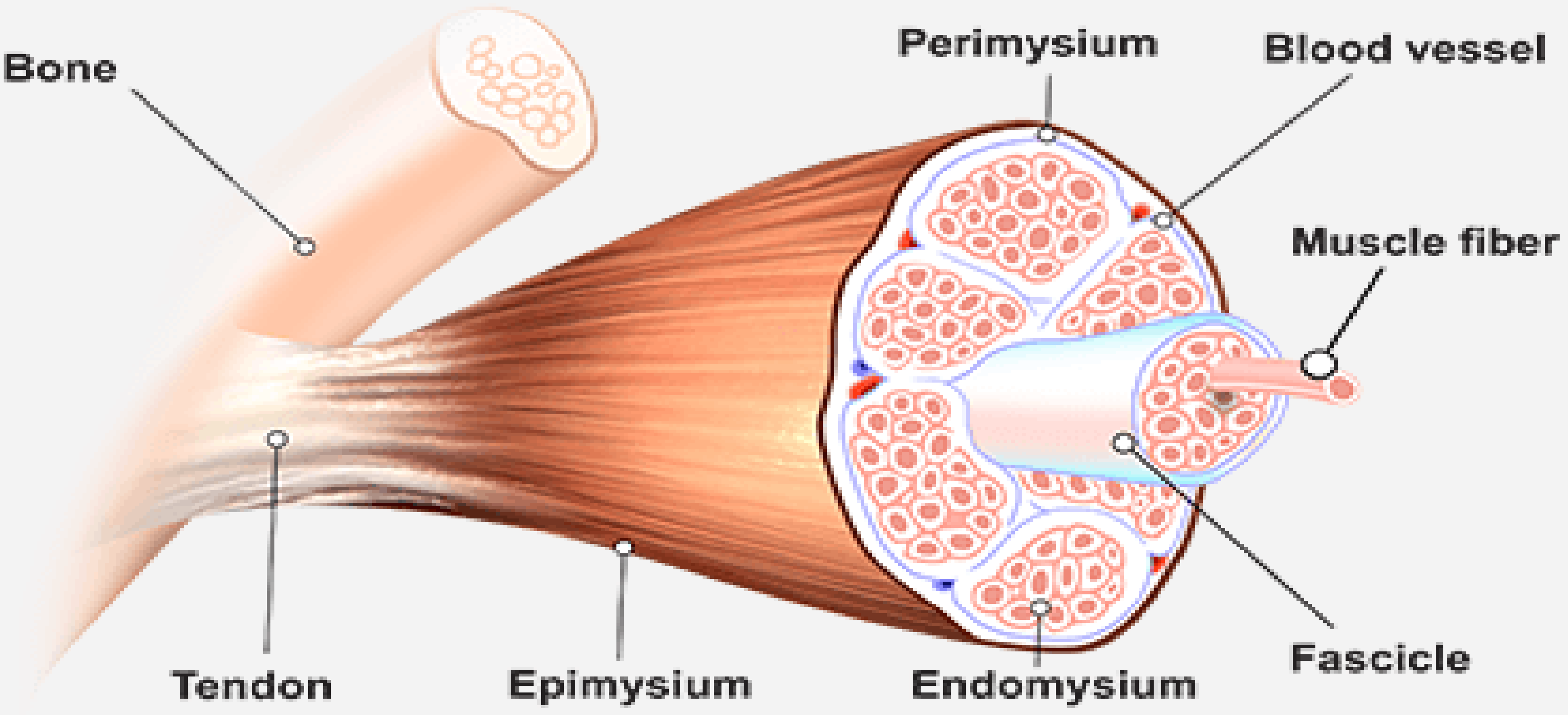
Skeletal Muscle

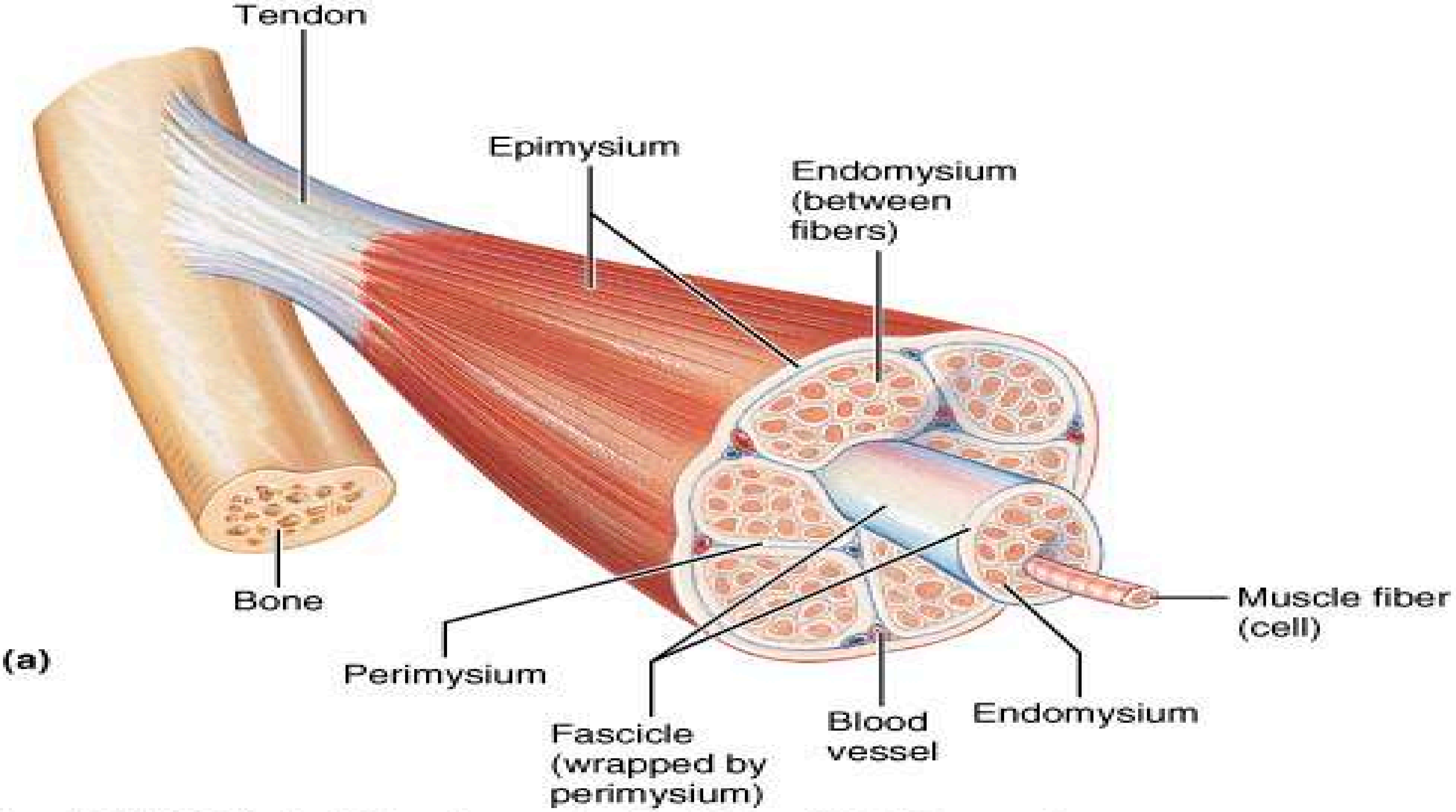
<u>Connective tissue</u>

1. Fascia (fibrous connective tissue under skin or around organs) superficial / under skin deep -- *endomysium* (fascia around a single muscle fiber) *perimysium* (fascia around a bunch of muscle fibers) *epimysium* (fascia around the entire muscle)



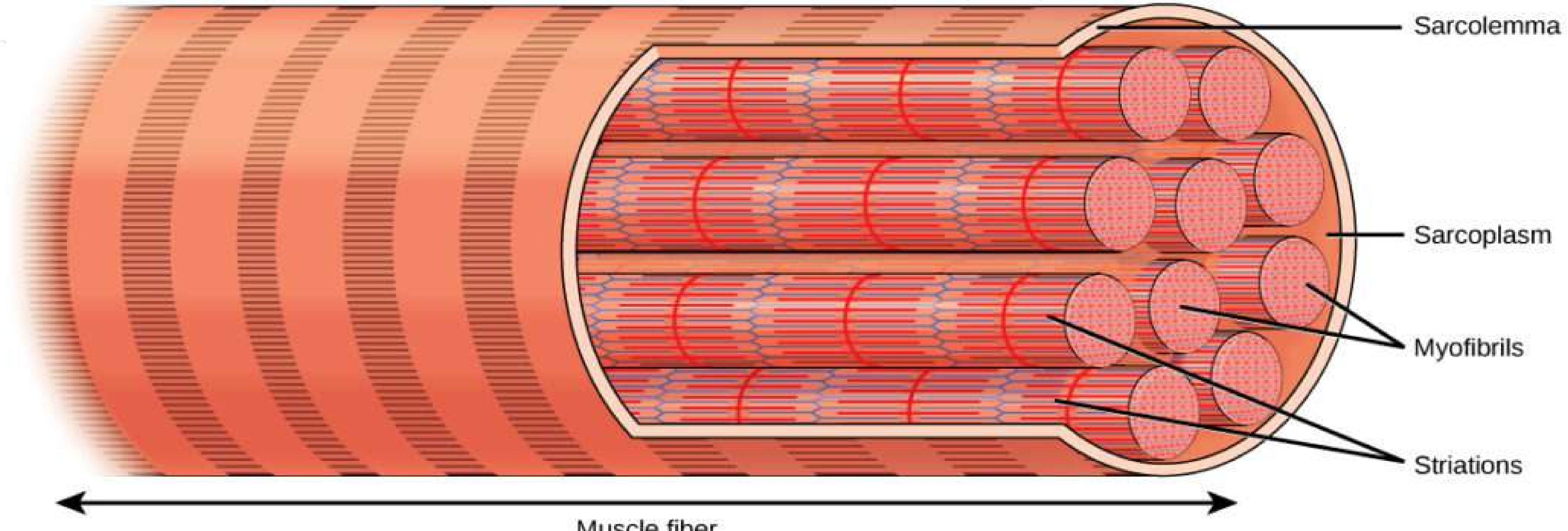
structure of skeletal muscle




Tendon
Epimysium
Endomysium
(between
fibers)
Bone
(a)
Perimysium
Fascicle
(wrapped by
perimysium)
Blood
vessel
Endomysium
Muscle fiber
(cell)

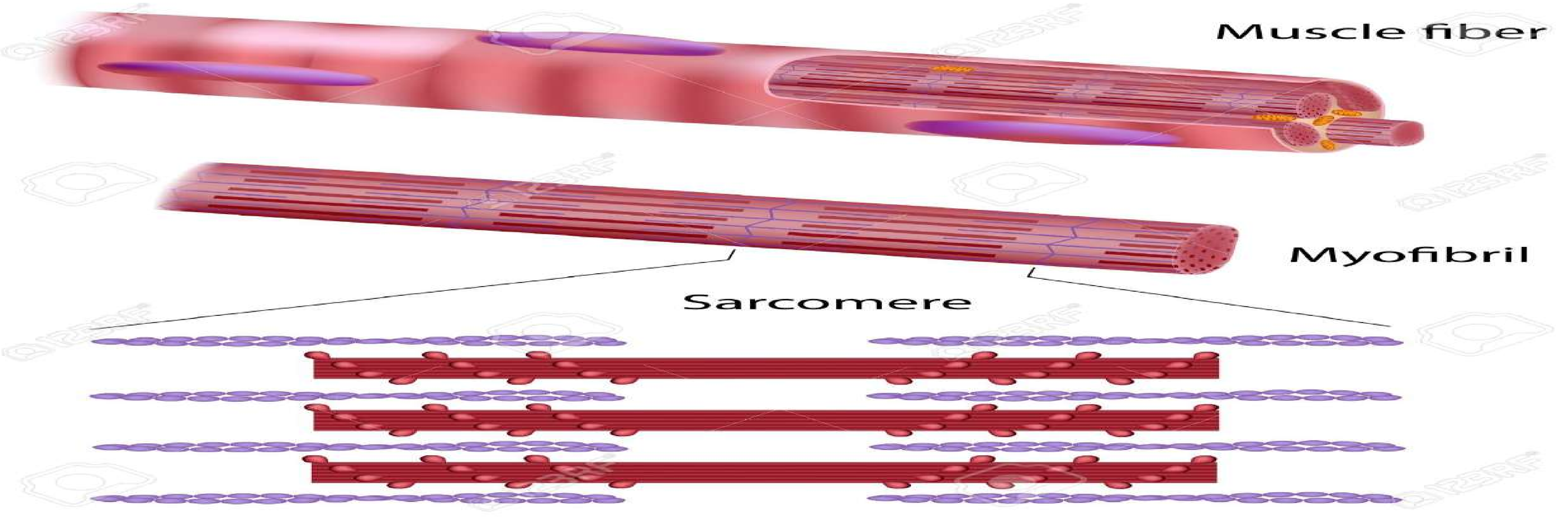
Muscle structure

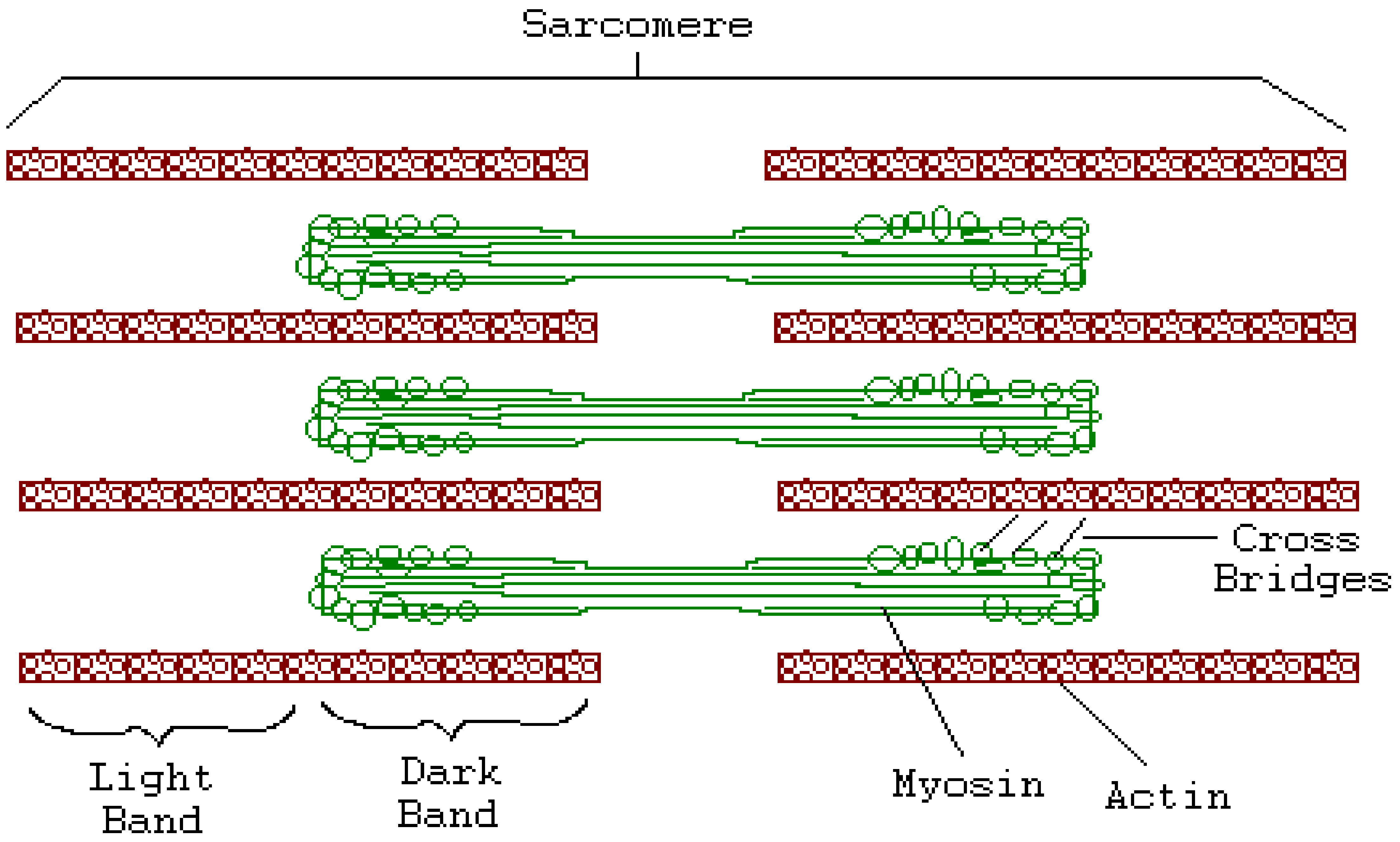
1. Muscle → bundle of muscle fibers (fascicle) → muscle fiber -- (single cell covered by a sarcolemma - plasma membrane / filled with sarcoplasm – cytoplasm / has lots of mitochondria for ATP) → myofibrils made of sarcomere sections which have a thick filament (w/ the protein myosin and its crossbridges) and a thin filament (w/ actin, troponin and tropomyosin)

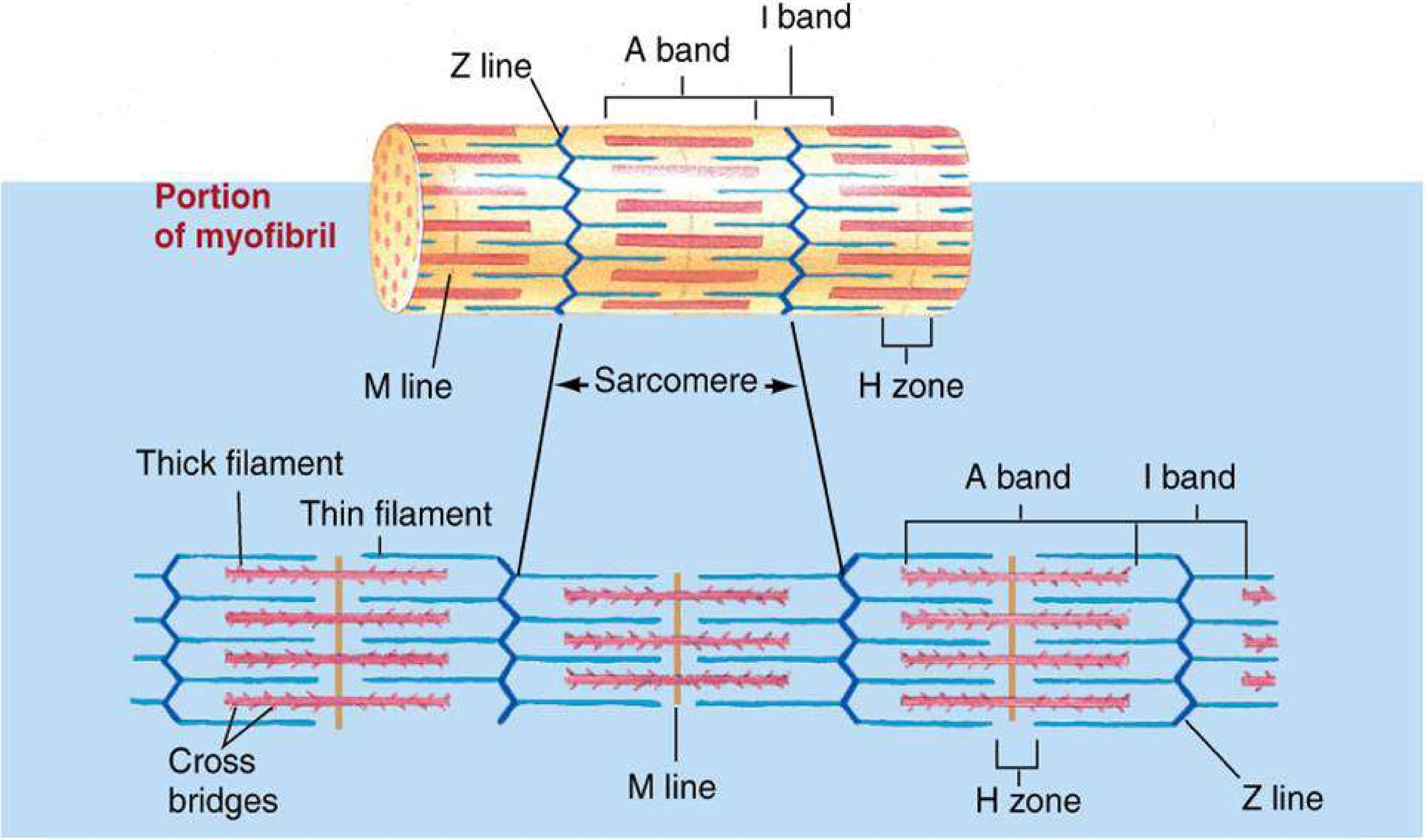


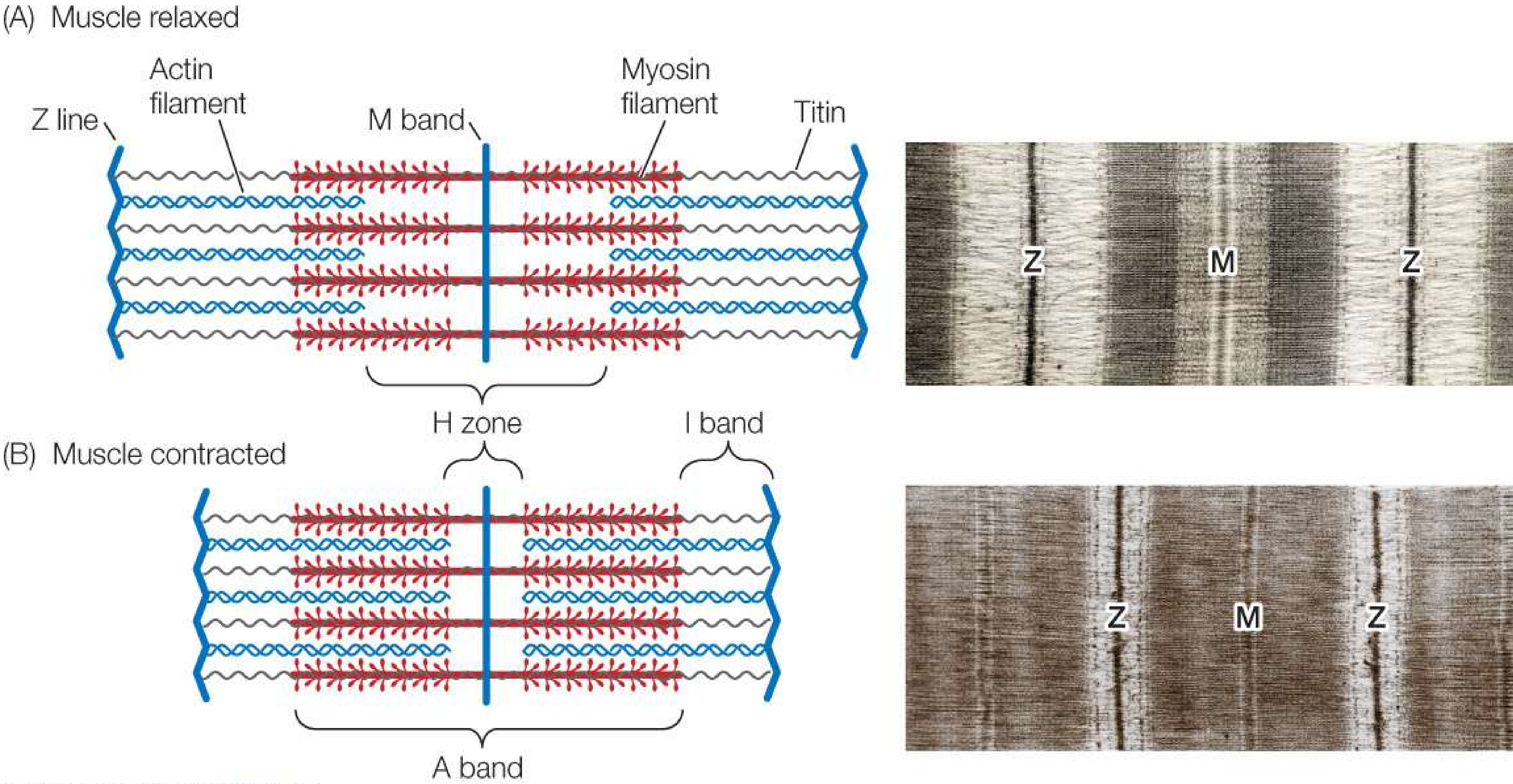
Muscle structure

1. M*uscle → bundle of muscle fibers (fascicle) → muscle fiber -- (single cell covered by a sarcolemma - plasma membrane / filled with sarcoplasm – cytoplasm / has lots of mitochondria for ATP)* → myofibrils made of sarcomere sections which have a thick filament (w/ the protein myosin and its crossbridges) and a thin filament (w/ actin, troponin and tropomyosin)



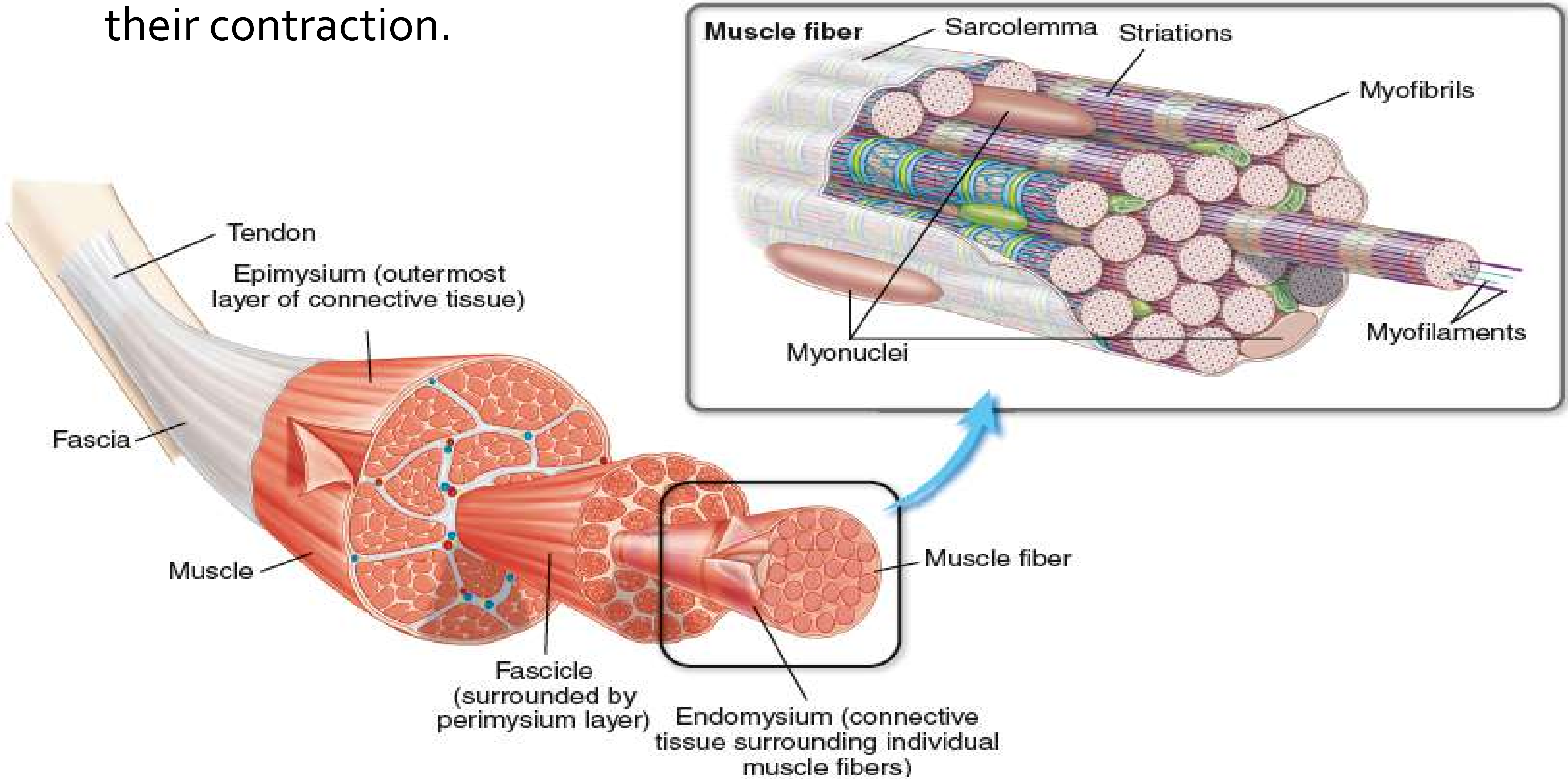

Sarcomere
Cross
Bridges
Light
Band
Dark
Band
Myosin
Actin


I band
A band
Z line
Portion
of myofibril
M line
Sarcomere
H zone
Thick filament
Thin filament
A band
I band
Cross
bridges
M line
H zone
Z line



33.3: © James Dennis/Phototake.

2. A myofibril does not run the entire length of the muscle fiber. They run parallel to each other to run the length of the cell. This increases the effect of their contraction.



https://www.youtube.com/watch?v=ousflrOzQHc
4:24

https://www.youtube.com/watch?v=BVcgO4p88AA&vl=en
2:48

https://www.youtube.com/watch?v=GneonFlcZG8
6:17

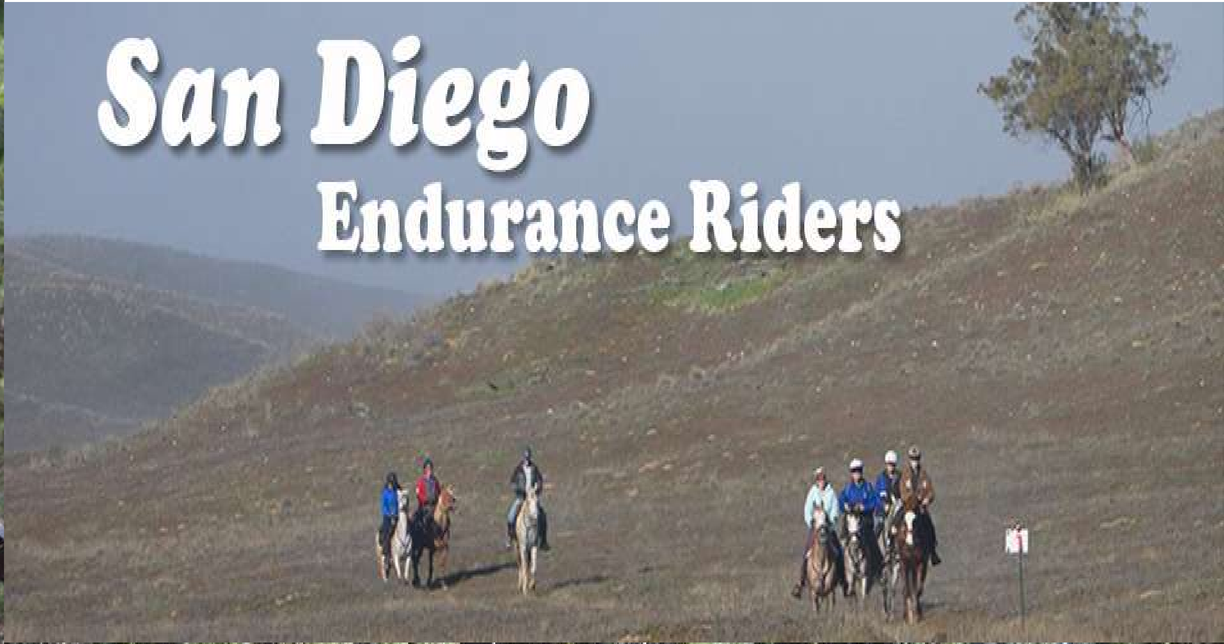
Muscle Types

MUSCLE FIBERS FACE OFF	
SLOW TWITCH	**FAST TWITCH**
Efficient in using oxygen	Do not burn oxygen to create energy
Delayed muscle firing	Fast to fire; best for explosive body movements
Do **not** fatigue easily	Tire out quickly
Best suited for: endurance sports, including cycling, marathon running and long-distance triathlons!	**Best suited for:** short bursts of activity, including sprinting races, pole vaulting and cross fit-style events

https://www.youtube.com/watch?v=bMqS9ad-1xM
Start at 133

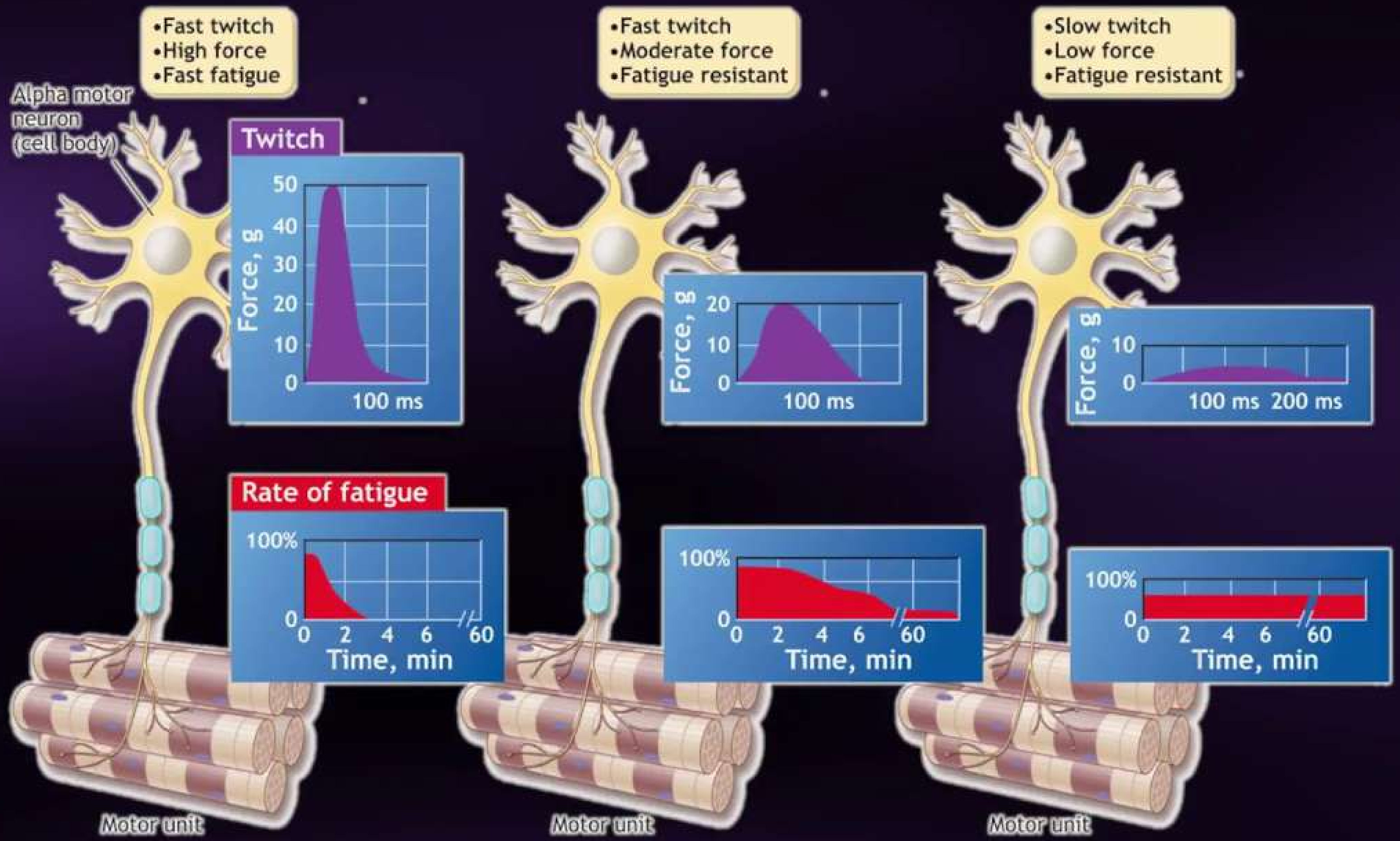
Thoroughbreds have an average of 80 to 90% fast-twitch muscle fibers, while Arabian and Standardbred horses are close to this level with about 75% fast-twitch fibers


19


San Diego
Endurance Riders


©Merri Melde-Endurance.net

https://www.photo.lynnesite.com/Clients/EventArchive/Coso-Junction-2015-2016-Season/i-7JH3CQ9/A

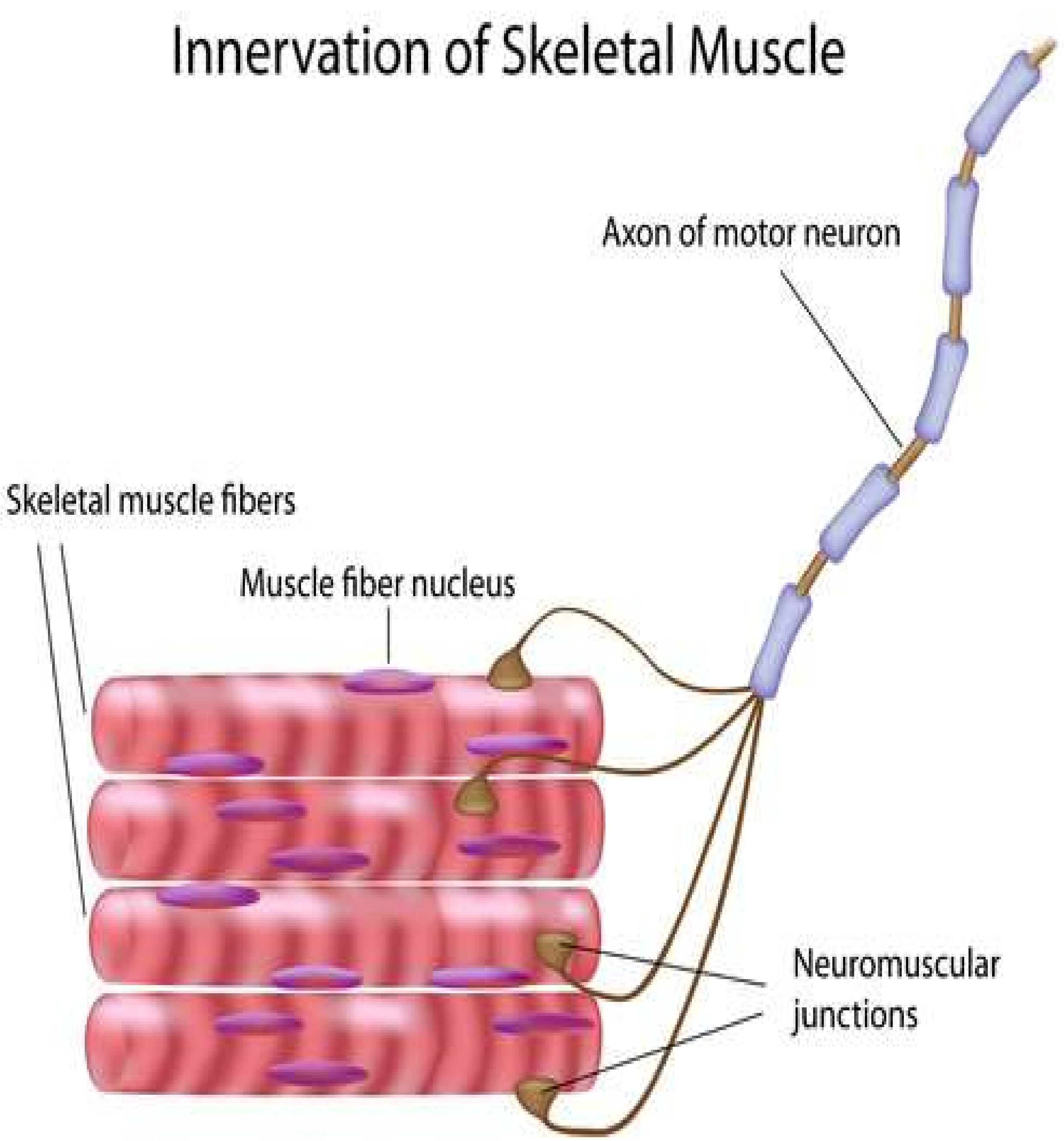


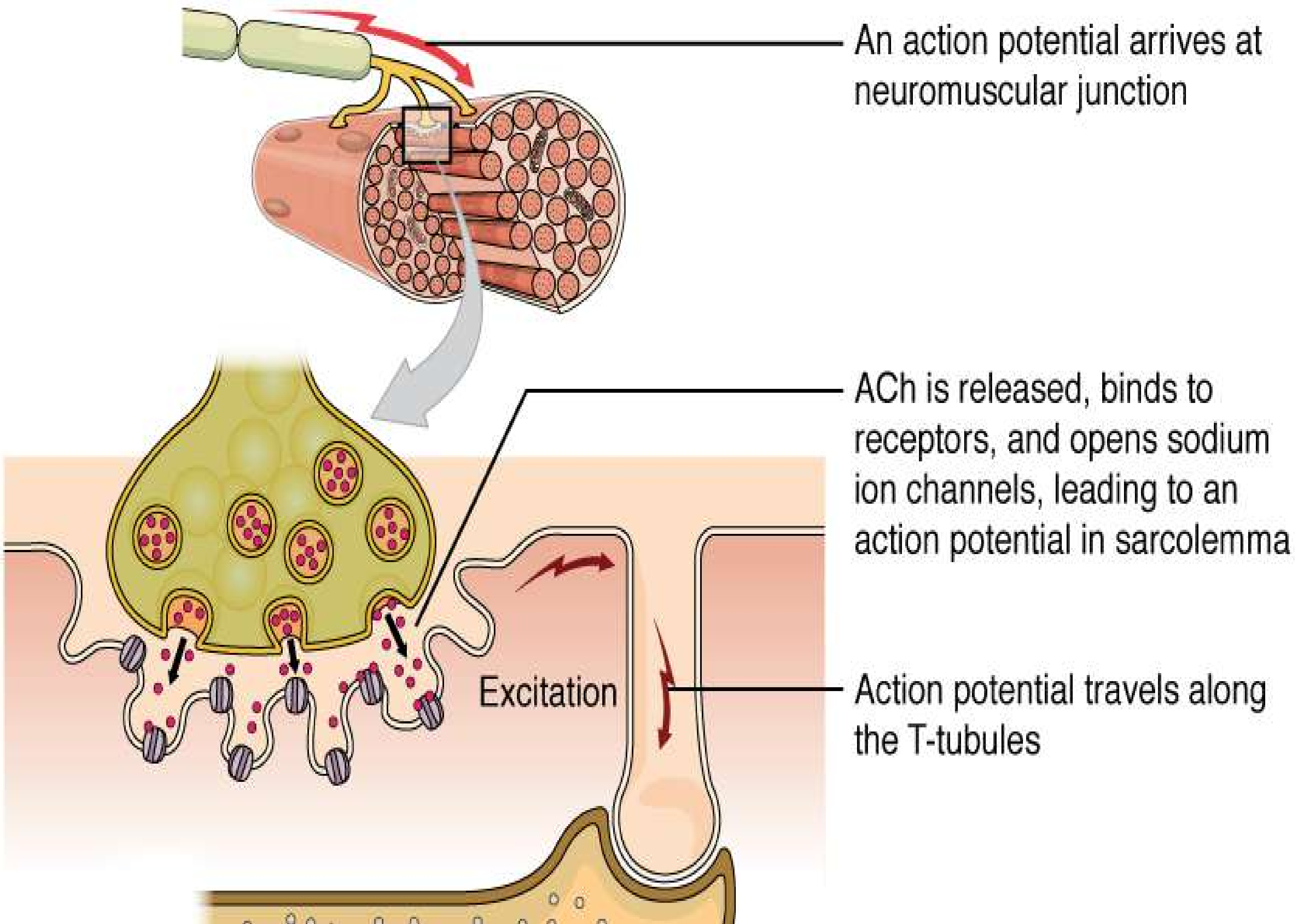
•Fast twitch
•High force
•Fast fatigue
Alpha motor neuron (cell body)
Twitch
Force, g
50
40
30
20
10
0
100 ms
Rate of fatigue
100%
0
0 2 4 6 60
Time, min
Motor unit
•Fast twitch
•Moderate force
•Fatigue resistant
Force, g
20
10
0
100 ms
100%
0
0 2 4 6 60
Time, min
Motor unit
•Slow twitch
•Low force
•Fatigue resistant
Force, g
10
0
100 ms 200 ms
100%
0
0 2 4 6 60
Time, min
Motor unit

<u>Muscular contraction and nervous impulses</u>

A. Events

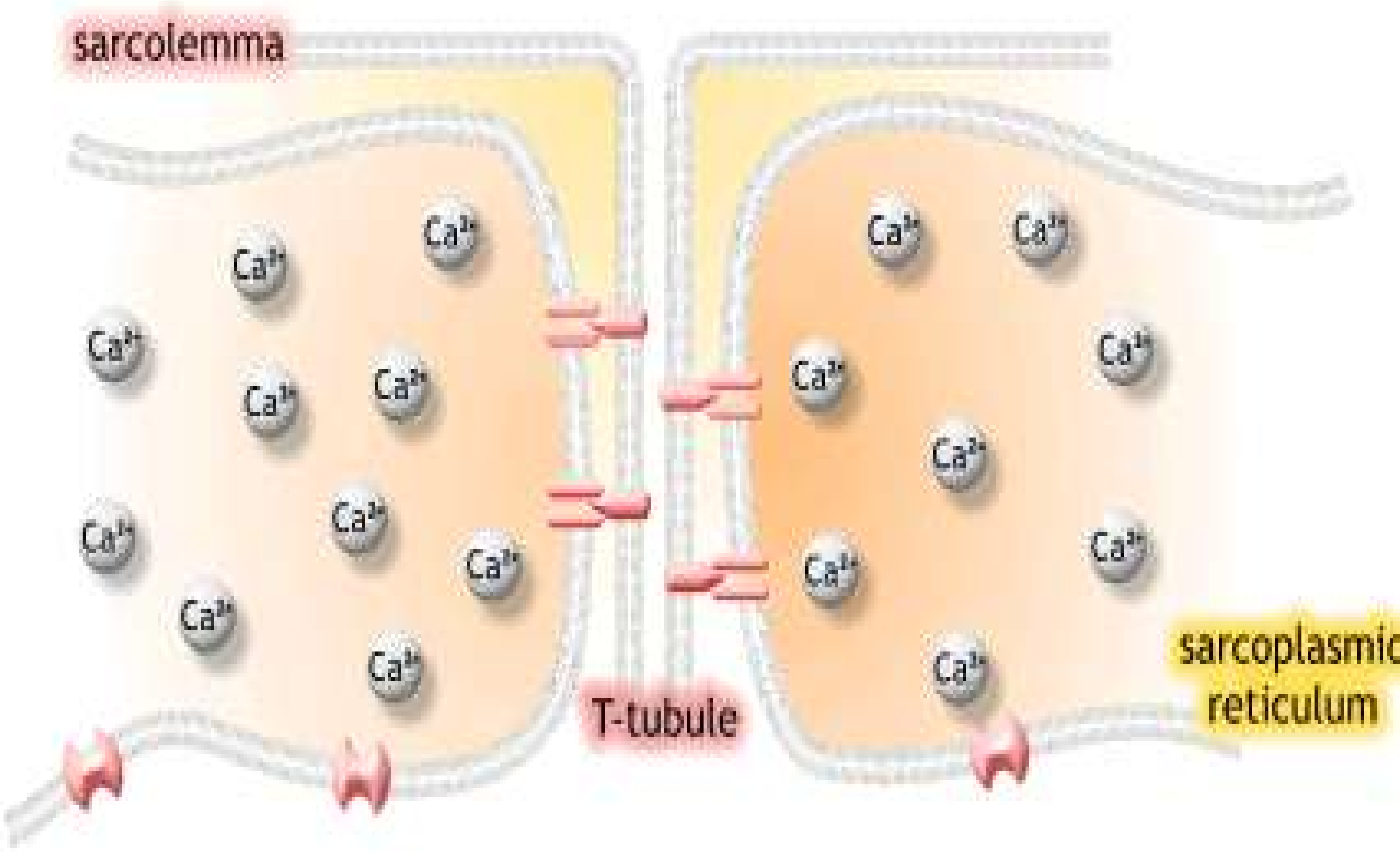
1. The sequence of events that result in the contraction of an individual muscle fiber begins with a signal—the neurotransmitter, ACh—from the motor neuron innervating that fiber. The local membrane of the fiber will depolarize as positively charged sodium ions (Na^+) enter, triggering an action potential that spreads to the rest of the membrane.



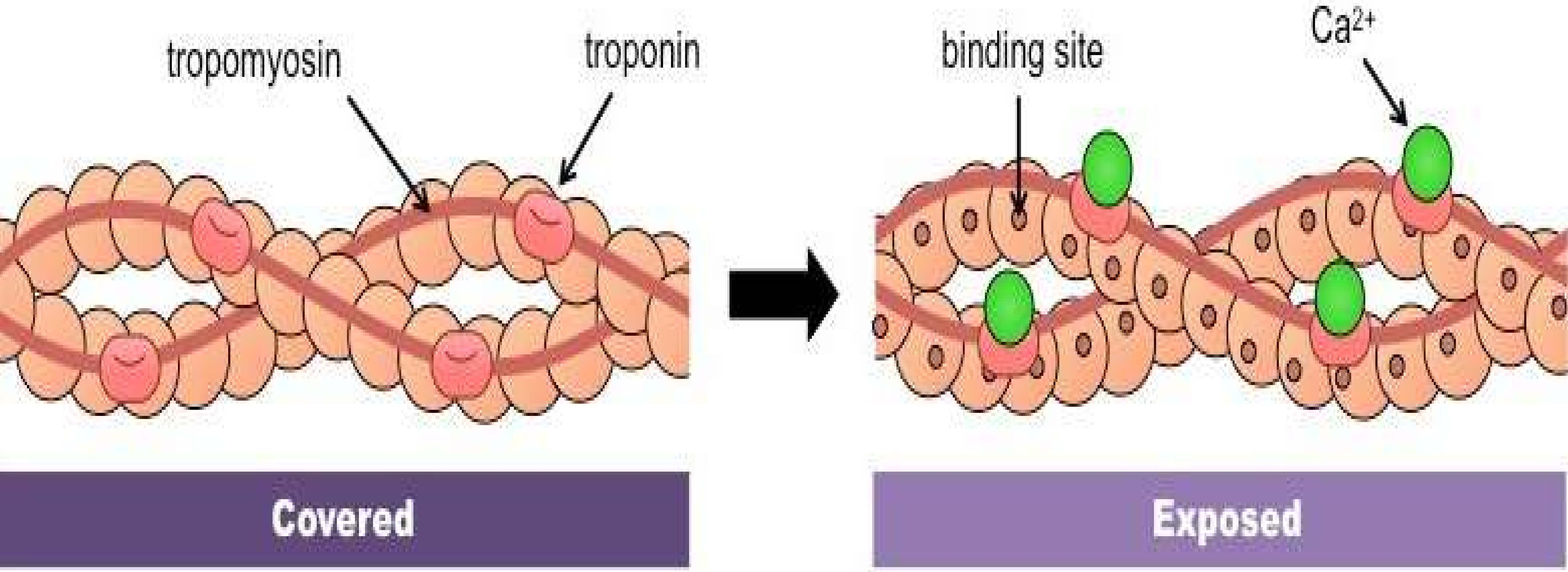


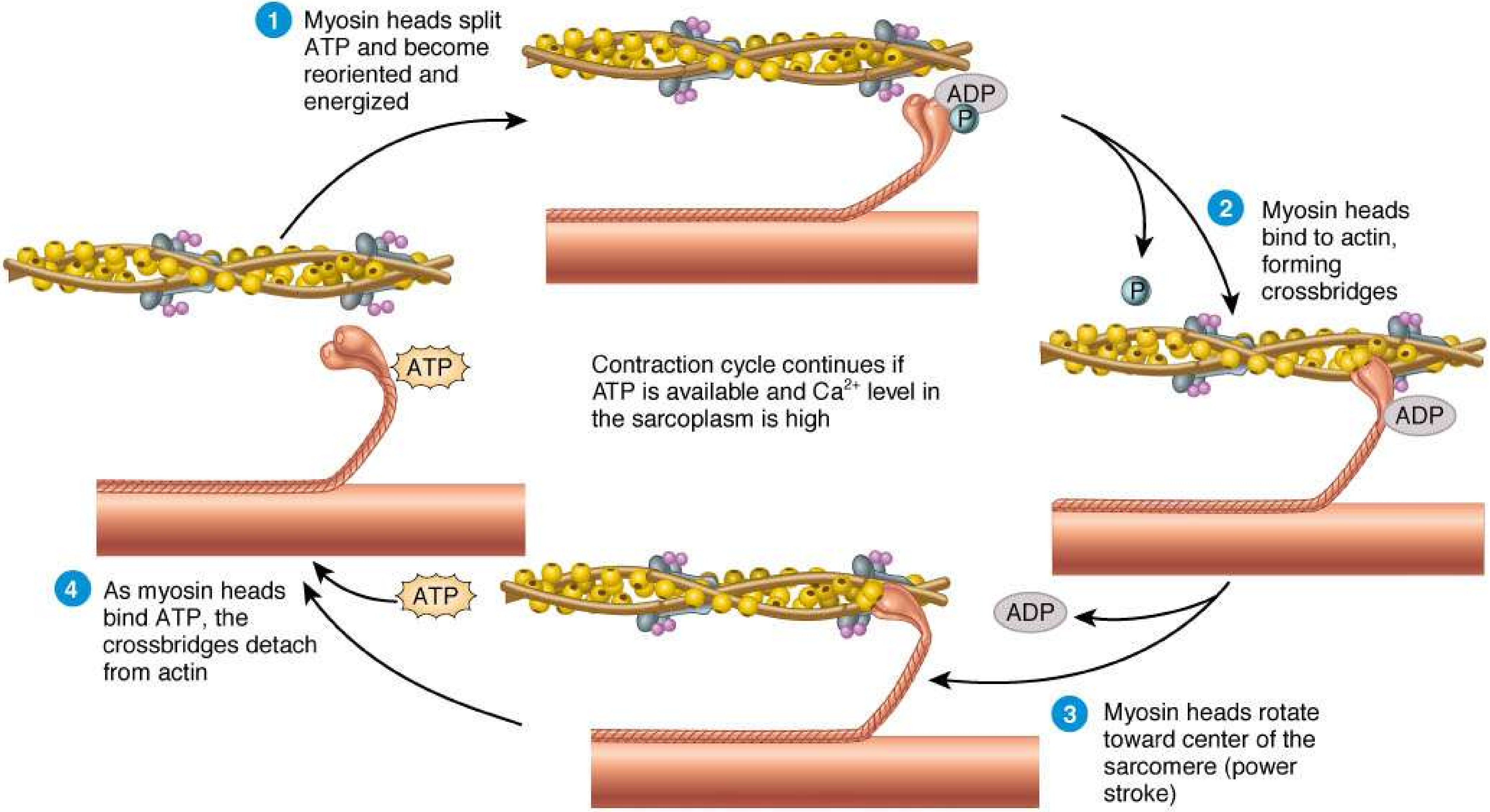
An action potential arrives at neuromuscular junction
ACh is released, binds to receptors, and opens sodium ion channels, leading to an action potential in sarcolemma
Excitation
Action potential travels along the T-tubules

2. This triggers the release of calcium ions (Ca^{++}) from storage in the sarcoplasmic reticulum (SR).

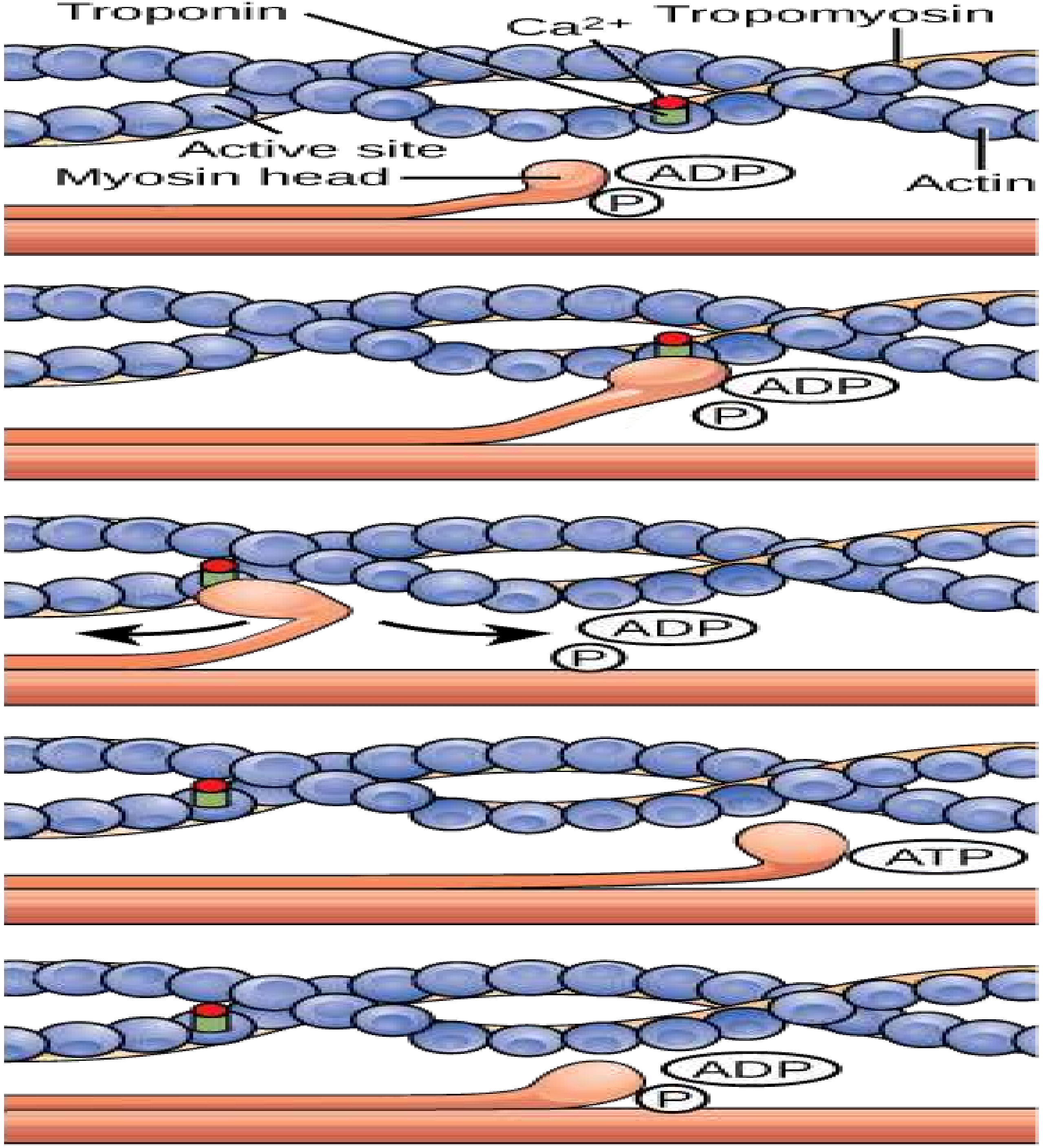


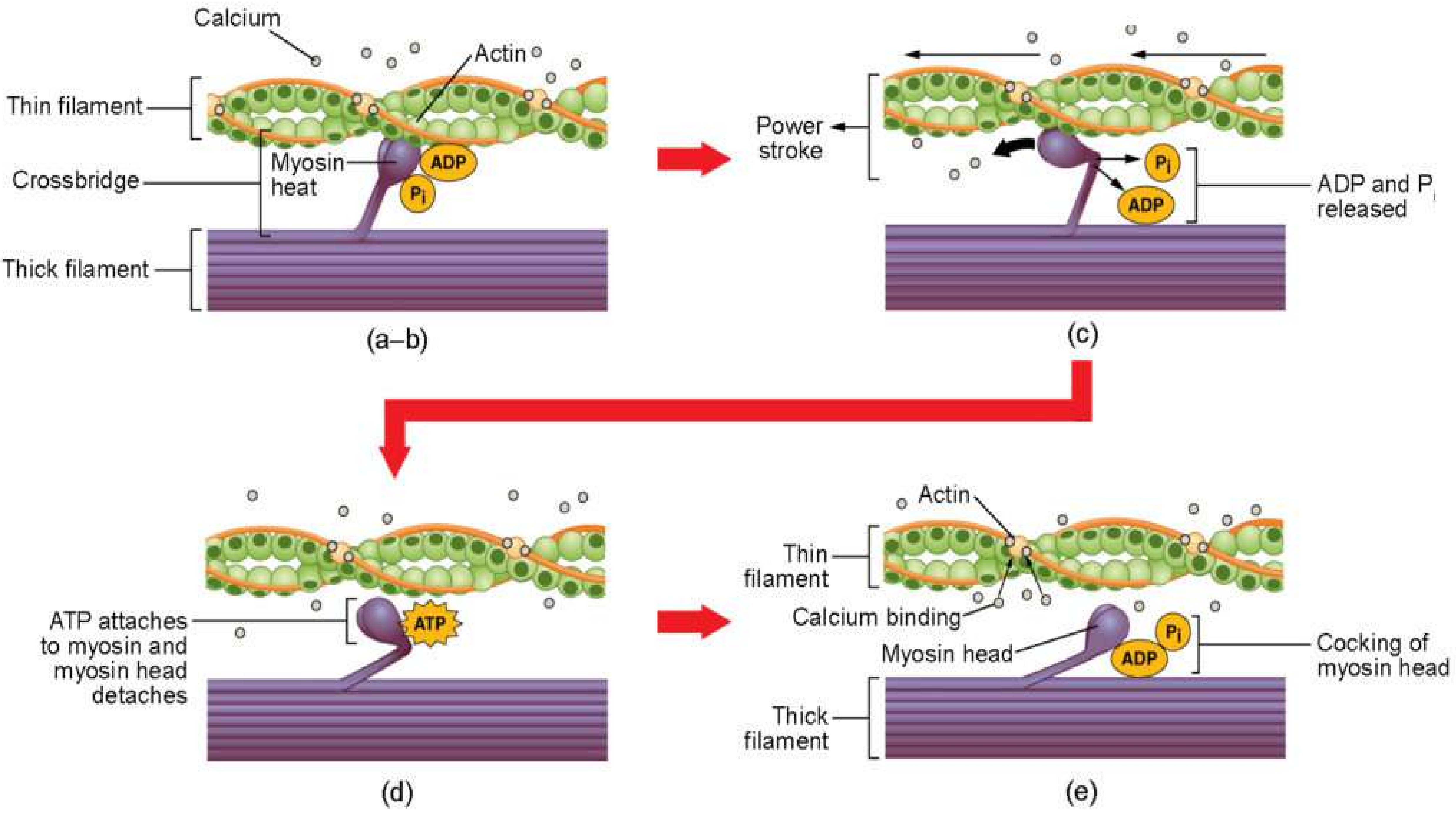
3. The Ca^{++} then binds to the troponin to initiates contraction, which is sustained by ATP. The binding of the Ca^{++} unshields the actin binding sites from the myosin. When the actin binding sites are uncovered, the myosin crossbridges are free to bind and, with the help of ATP, move the actin filament.




1 Myosin heads split ATP and become reoriented and energized
ADP
P
2 Myosin heads bind to actin, forming crossbridges
P
ADP
ATP
Contraction cycle continues if ATP is available and Ca2+ level in the sarcoplasm is high
ADP
ATP
4 As myosin heads bind ATP, the crossbridges detach from actin
3 Myosin heads rotate toward center of the sarcomere (power stroke)

1. The active site on actin is exposed as Ca^{2+} binds troponin.
2. The myosin head forms a cross-bridge with actin.
3. During the power stroke, the myosin head bends, and ADP and phosphate are released.
4. A new molecule of ATP attaches to the myosin head, causing the cross-bridge to detach.
5. ATP hydrolyzes to ADP and phosphate, which returns the myosin to the "cocked" position.

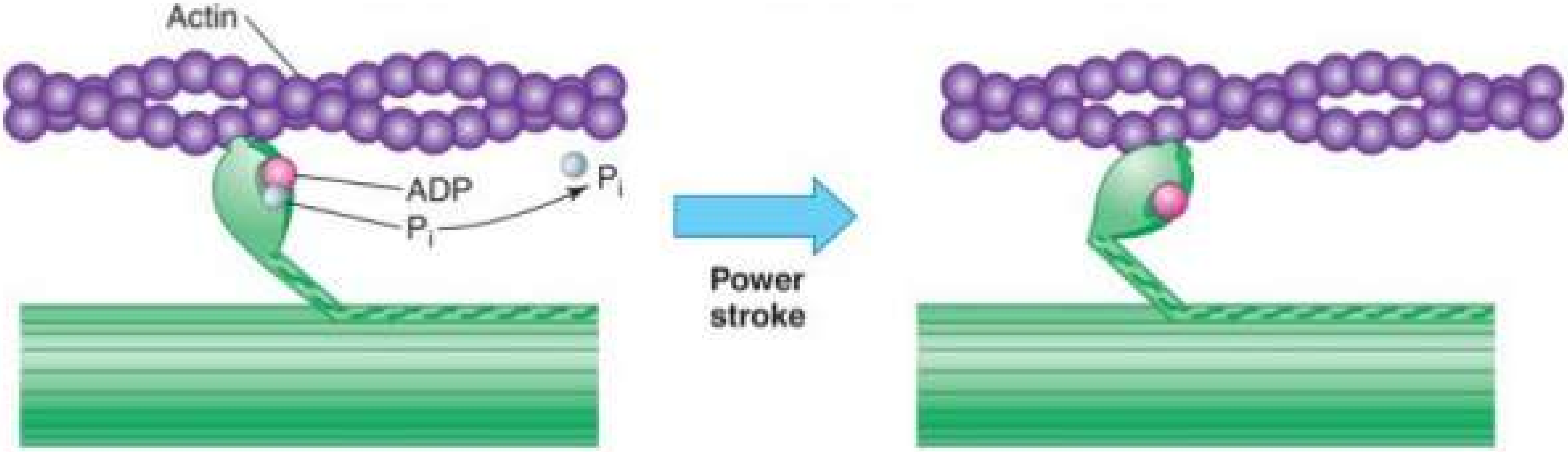




Calcium
Actin
Thin filament
Crossbridge
Myosin
heat
ADP
P_i
Thick filament
(a–b)
Power
stroke
P_i
ADP
ADP and P_i
released
(c)
ATP attaches
to myosin and
myosin head
detaches
ATP
(d)
Actin
Thin
filament
Calcium binding
Myosin head
P_i
ADP
Cocking of
myosin head
Thick
filament
(e)

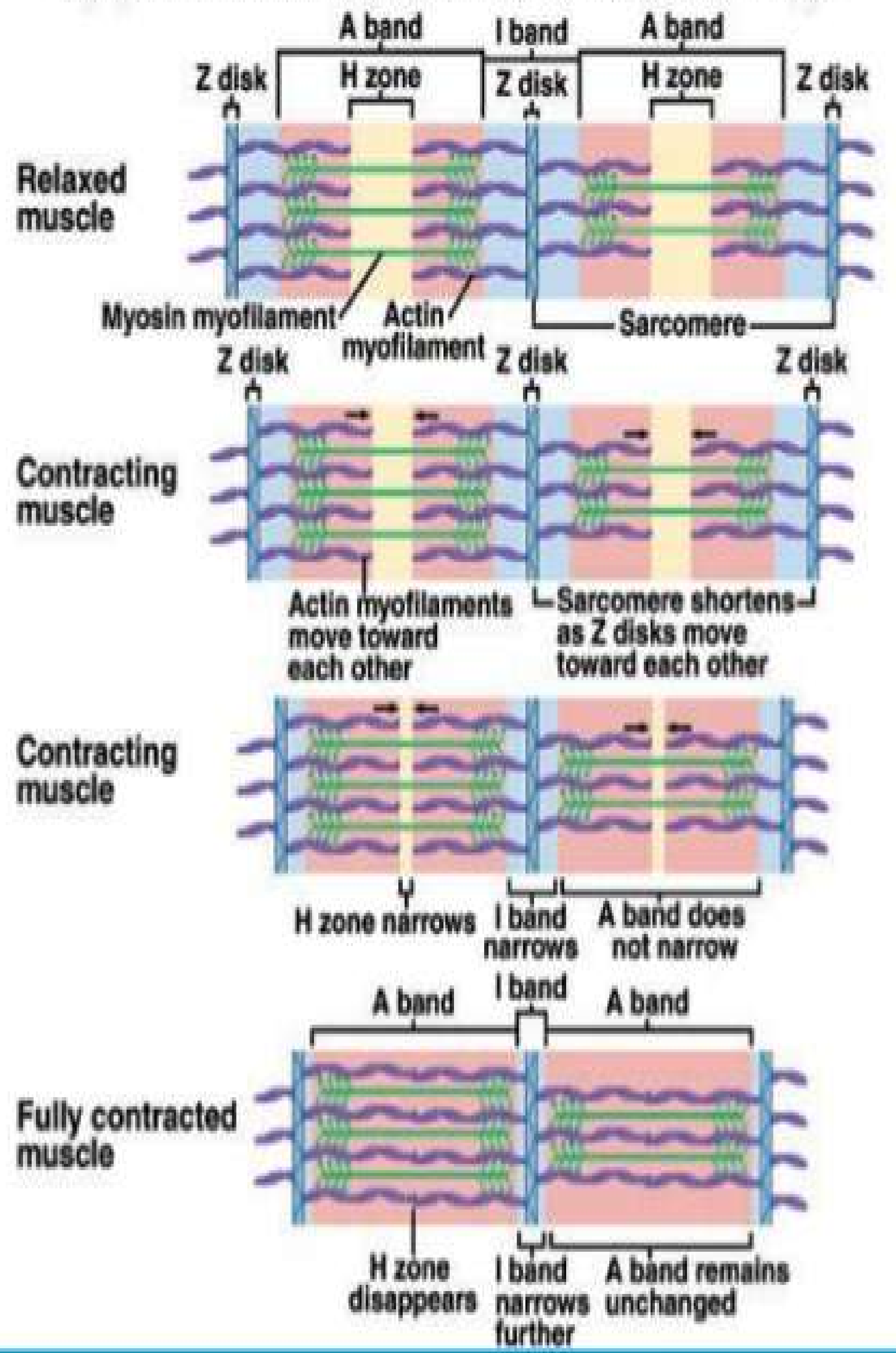
4. One movement is called a power stroke.

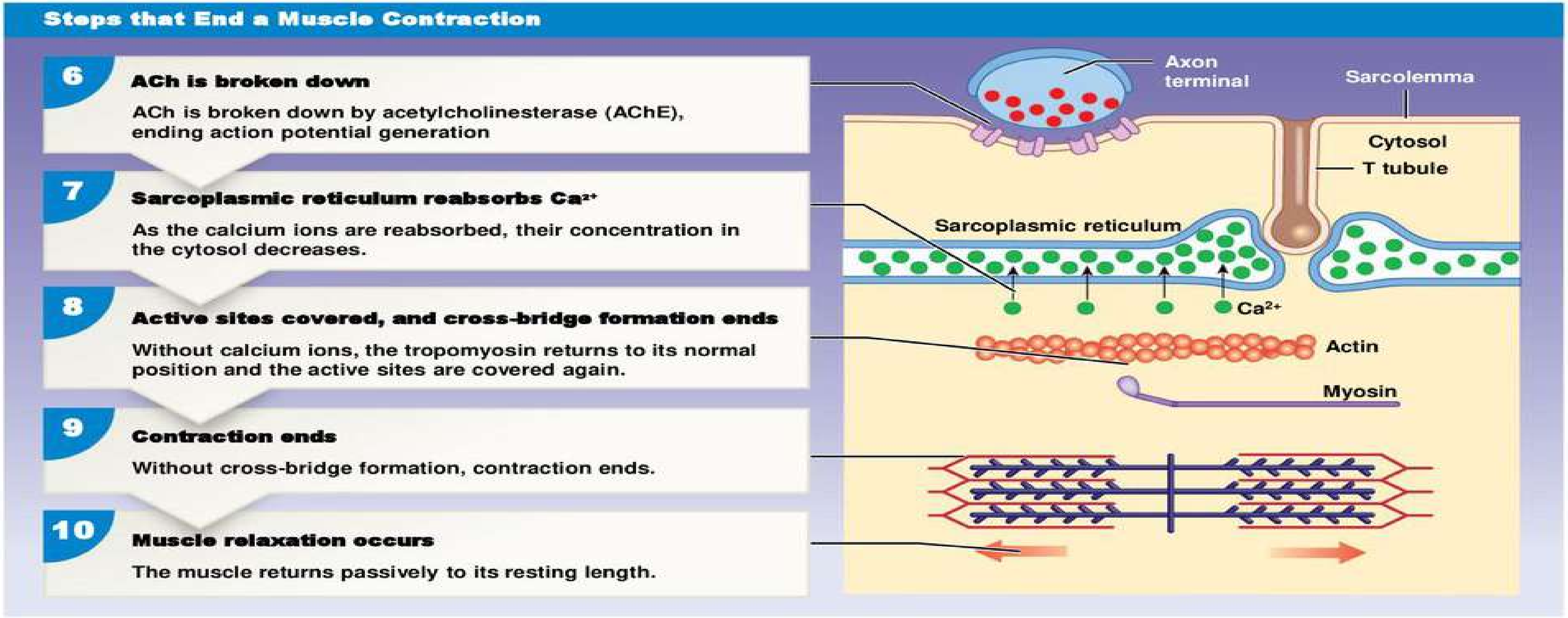
- Myosin can't bind to actin unless it is "cocked" by ATP
  - After binding, myosin undergoes conformational change (power stroke) which exerts force on actin
  - After power stroke myosin detaches



5. As long as Ca^{++} ions remain in the sarcoplasm to bind to troponin, which keeps the actin-binding sites "unshielded," and as long as ATP is available to drive the cross-bridge cycling and the pulling of actin strands by myosin, the muscle fiber will continue to shorten to an anatomical limit.

https://www.youtube.com/watch?v=U2TSaz8-yNQ





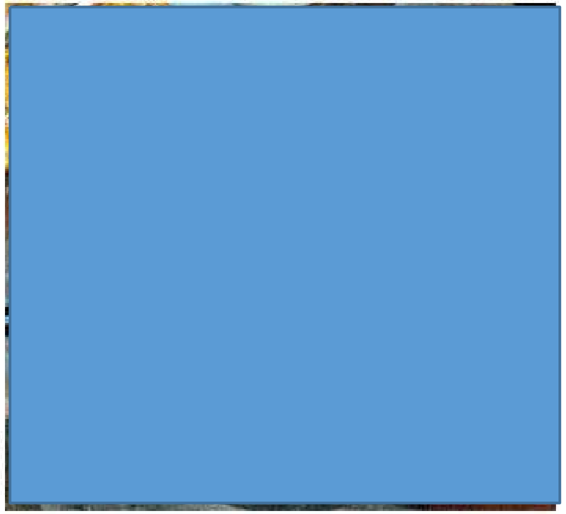
6. Muscle contraction usually stops when signaling from the motor neuron ends, which repolarizes the sarcolemma and T-tubules, and closes the voltage-gated calcium channels in the SR. Ca^{++} ions are then pumped back, using ATP, into the SR, which causes the tropomyosin to reshield (or re-cover) the binding sites on the actin strands.

7. A muscle also can stop contracting when it runs out of ATP and becomes fatigued

B. Rigor mortis results when death leads to a leaking out of the Ca^{+2} ions from the sarcoplasmic reticulum into the sarcoplasm of the muscle cell. This causes the troponin to uncover the myosin binding sites and a power stroke to occur. However, since the person is dead, there is no ATP available to detach the myosin cross bridges. This leads to a sustained contraction - stiff

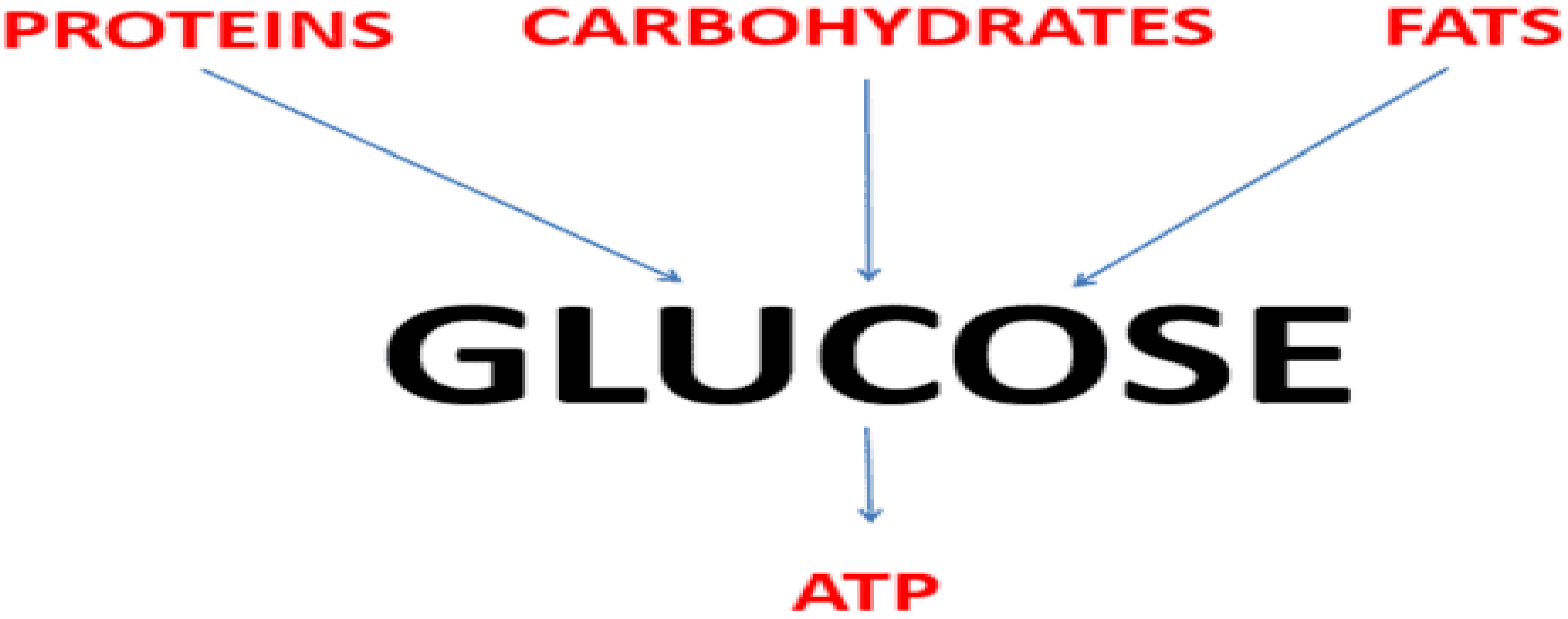
Rigor Mortis

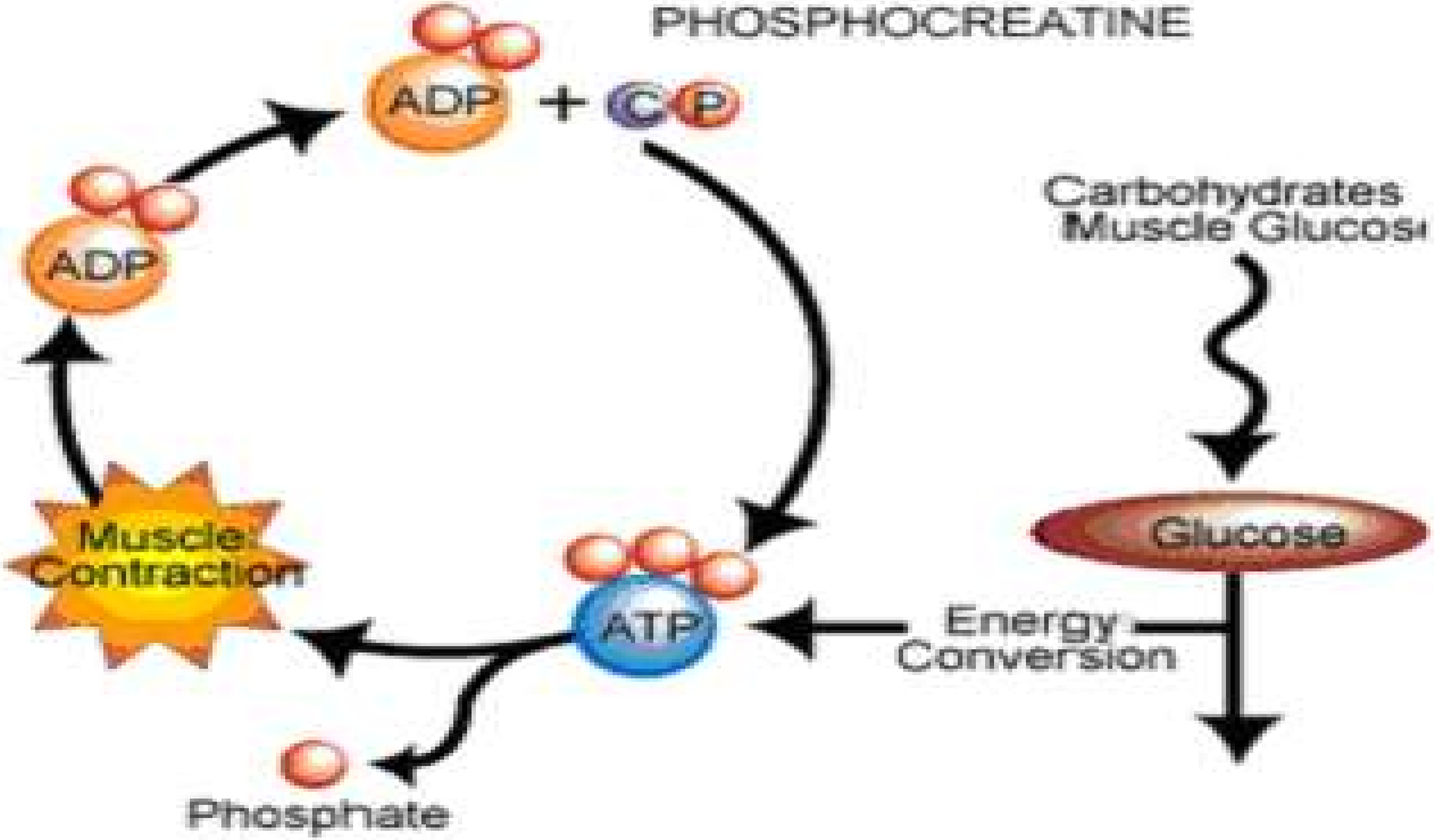
- After death, calcium ions start to leak out of SER
- Causes muscle contraction cycle to start
- ATP synthesis has stopped → cell runs out of ATP
- Crossbridges can't break apart → muscles in a state of contraction
- Starts about 3-4 hours after death
- Lasts about 24 hours (crossbridges are broken down)

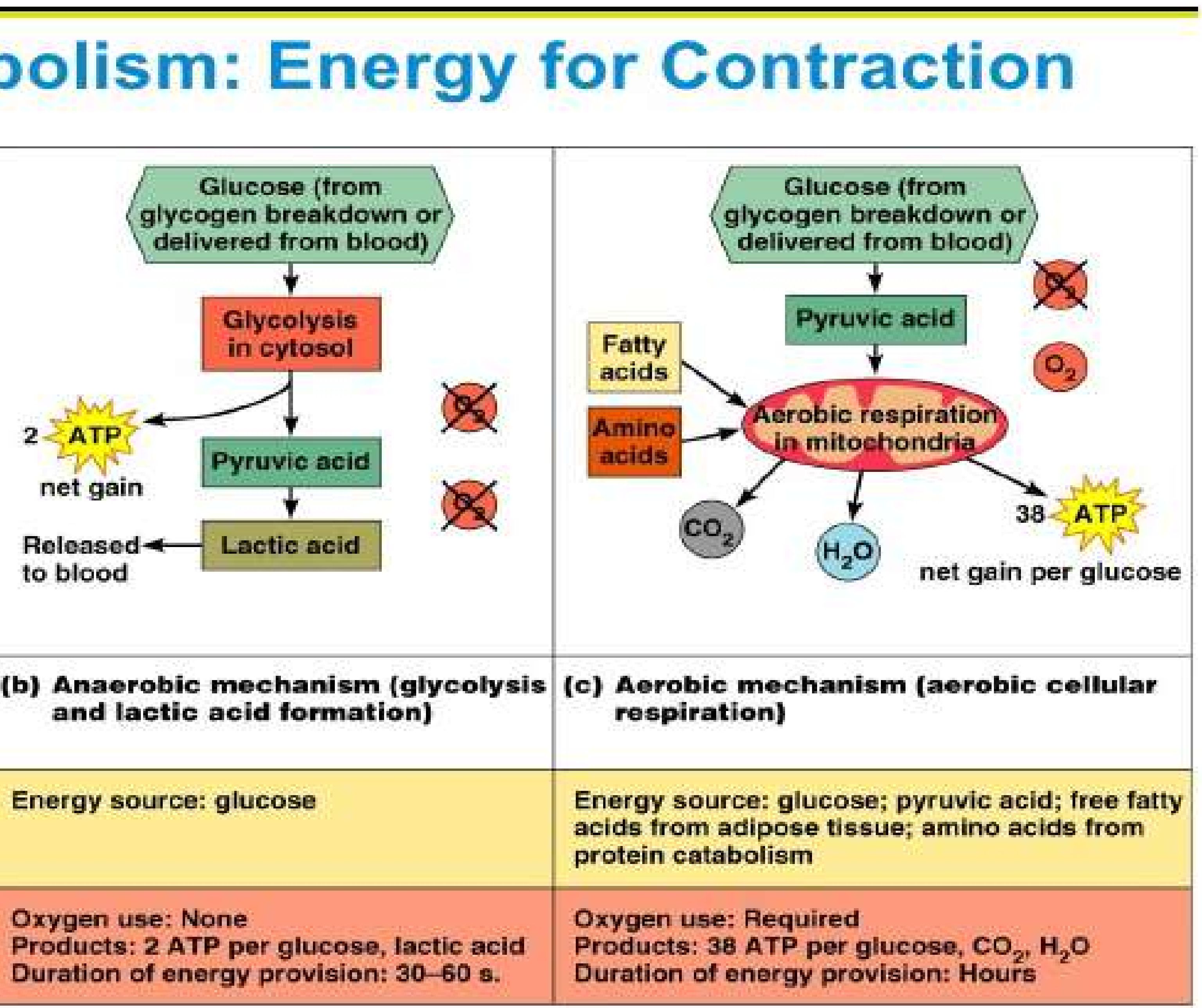


C. Energy

1. ATP - there is enough stored for 5 seconds of contraction
2. Creatine phosphate - there is enough stored for 15 seconds of contraction



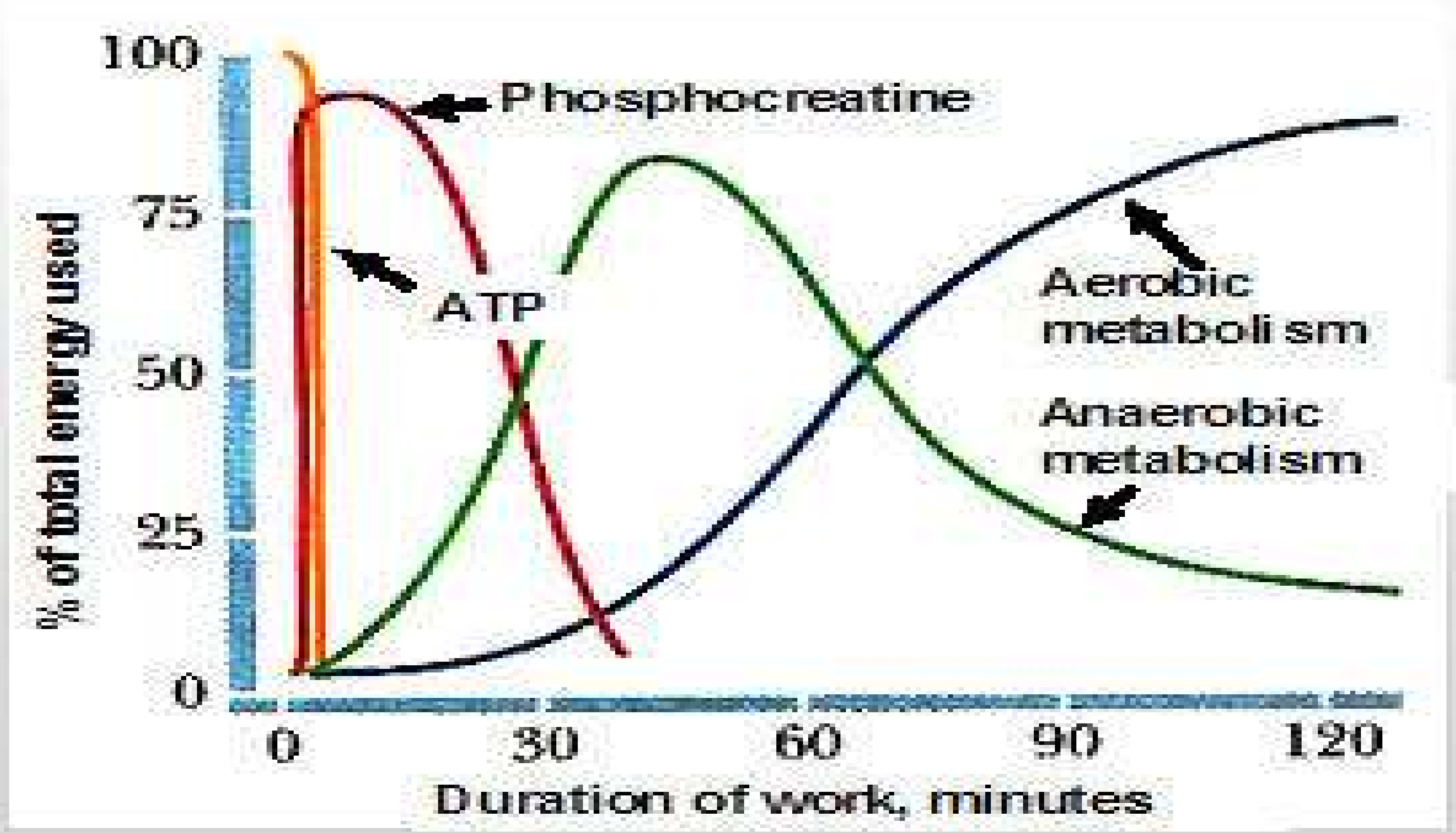

PHOSPHOCREATINE
ADP
+
C
P
ADP
Carbohydrates
Muscle Glucos
Muscle
Contraction
Glucose
ATP
Energy
Conversion
Phosphate



3. Anaerobic respiration (glycolysis) - the breakdown of stored glucose stored as glycogen, to create pyruvic acid and ATP - enough energy for 30 seconds

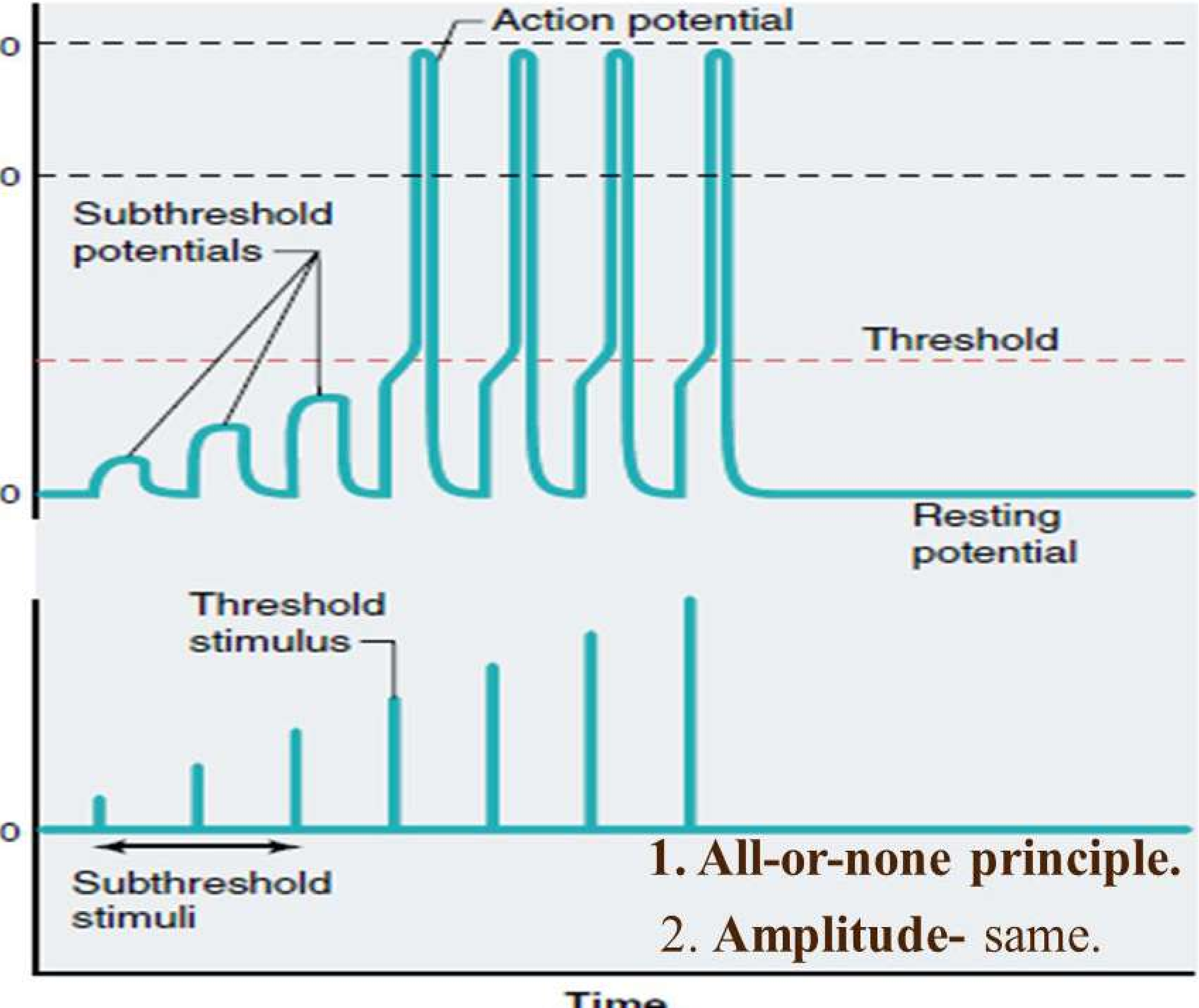
4. Aerobic respiration uses pyruvic acid and oxygen to create ATP. This can provide energy as long as oxygen and nutrients last. Aerobic is the muscle's preferred choice since it can last the longest

Energy Sources in Working Muscles



Differences between anaerobic and aerobic respiration

Aerobic respiration	Anaerobic respiration
• Requires oxygen • Occurs in the mitochondria of cells • Produces a lot of ATP per glucose molecule • Used when heart rate and breathing rate rise	• Occurs in the cytoplasm of cells • Doesn't require oxygen • Used during the first 1-2 minutes of exercise • Produces less ATP per glucose molecule



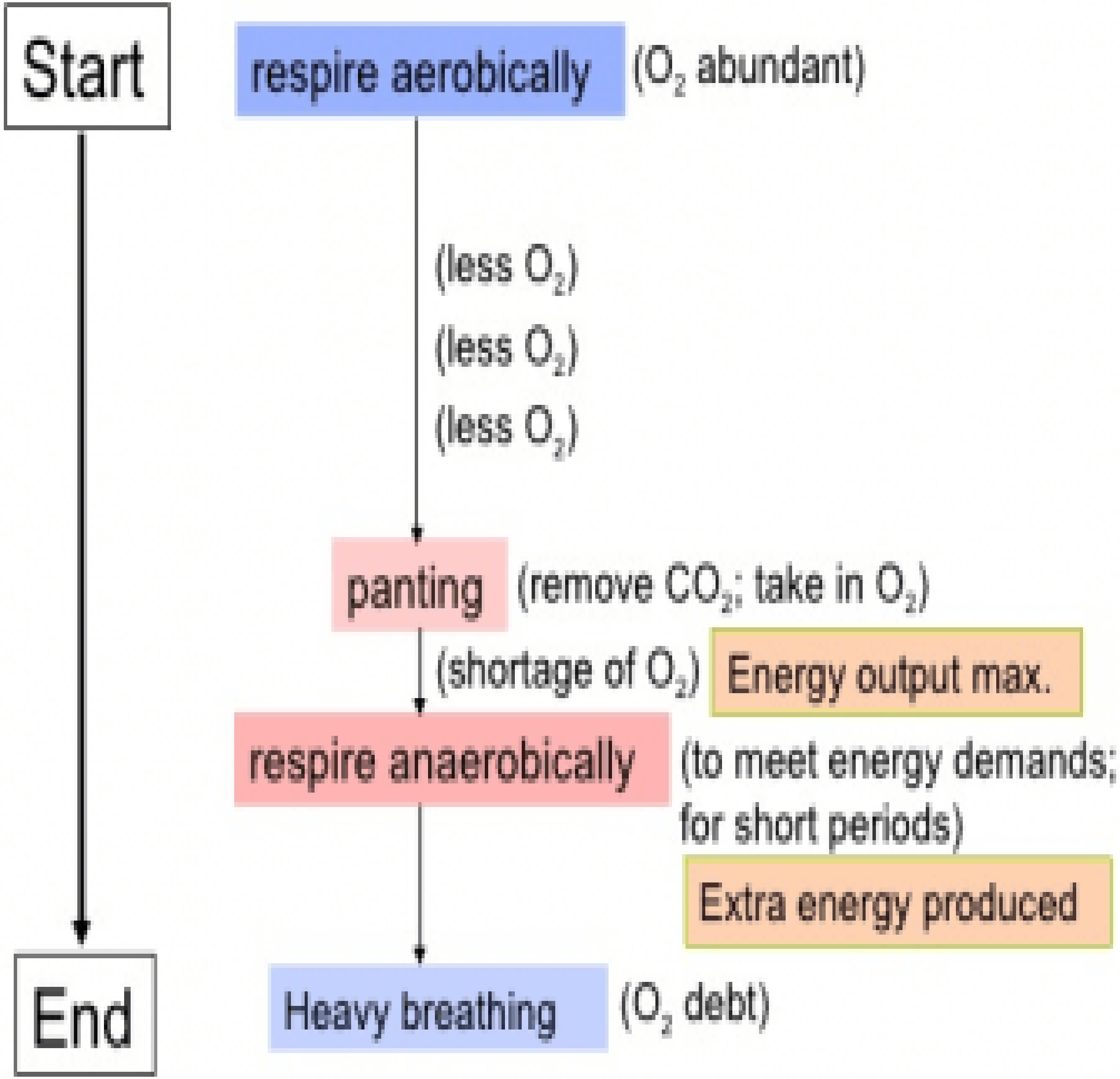
D. All or none principle

1. In order to contract, muscles need a certain level of stimulus, the threshold, from a nerve. If the impulses is not up to the level, the muscle will not contract at all.

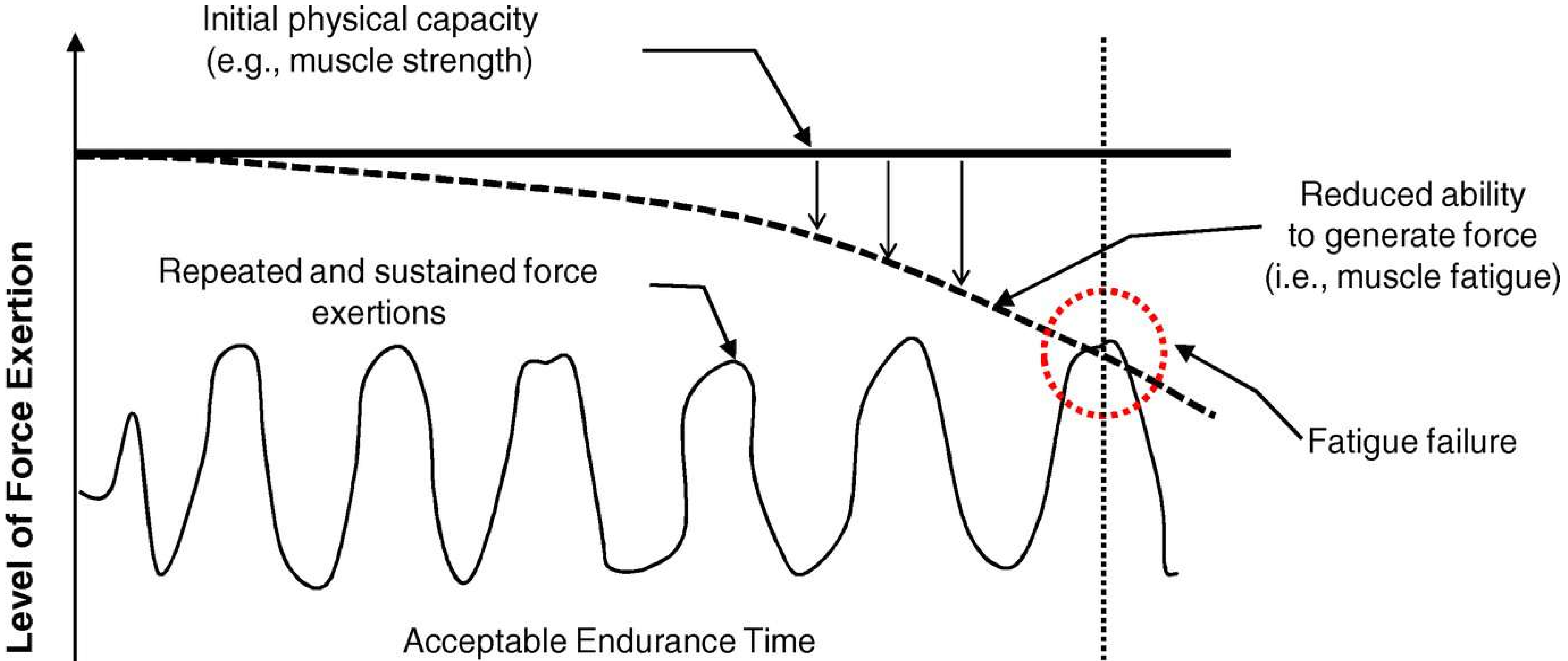
2. Muscle fibers do not partially contract. If there is a weak muscular action, it is not because the fibers contracted weakly. Muscles fibers always contract to their full ability. A weak muscle action is because only a few muscle fibers contracted. It's a number thing.

E. Homeostasis

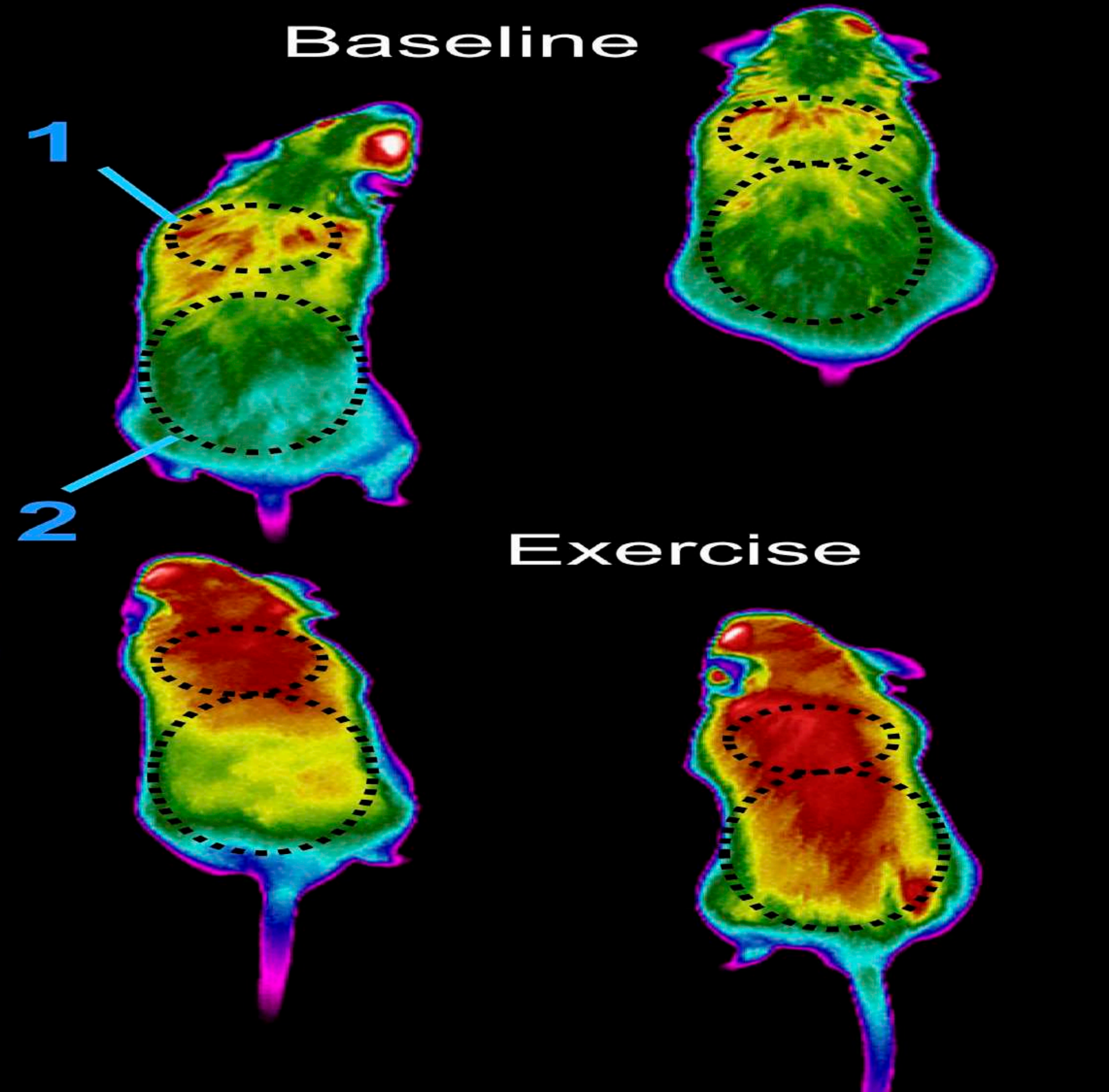
1. Oxygen debt – the amount of oxygen necessary to return body systems to normal after heavy exercise. Lactic acid accumulation in muscle tissue causes the hard breathing needed to pay the debt



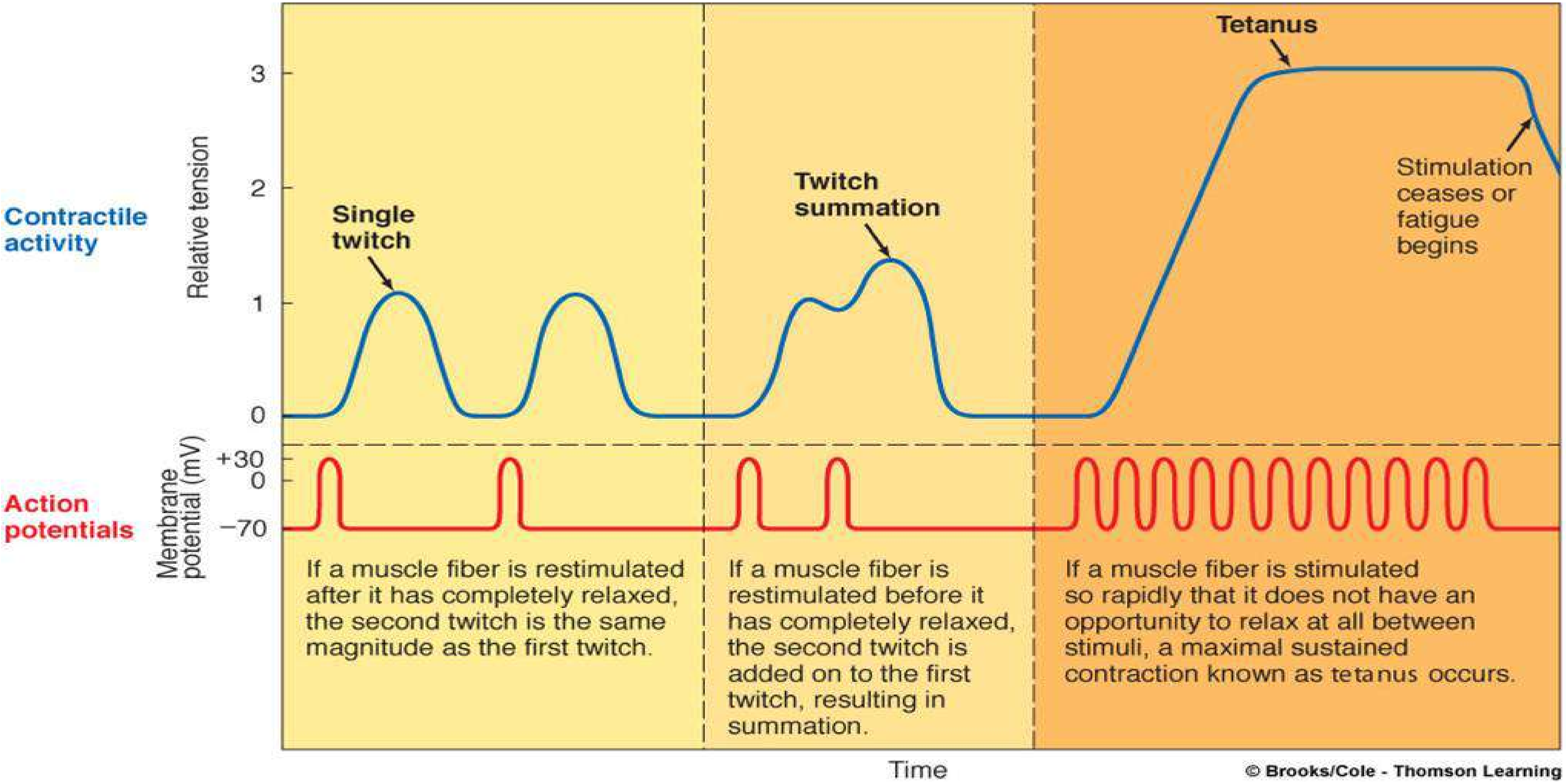
2. Muscle fatigue - the inability of a muscle to sustain its contractile strength. Sustained contraction leads to a body depletion of oxygen and glycogen. The inability of muscle to "go on" causes them to stop, so that oxygen and glycogen levels can be returned to normal.



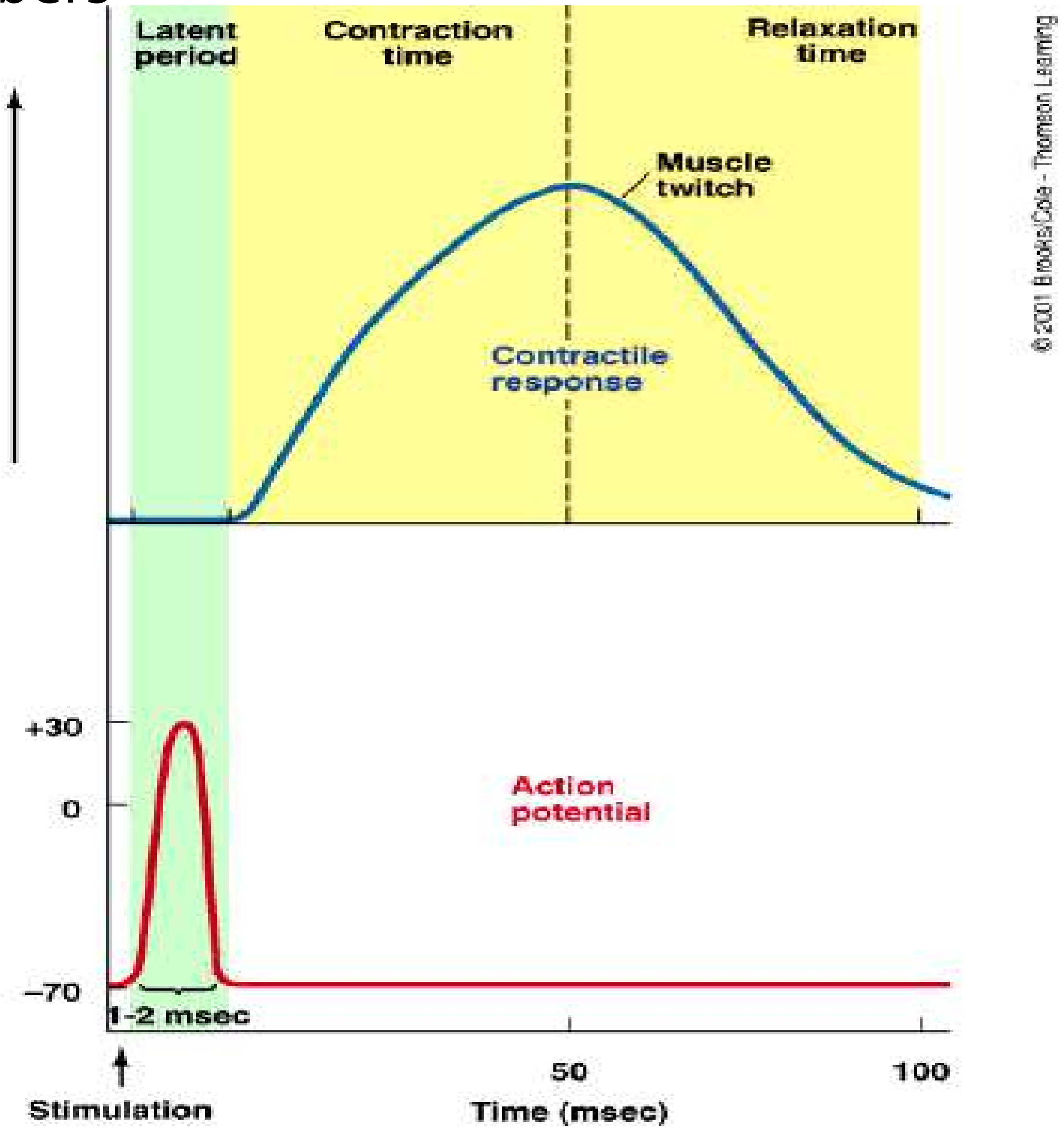
3. Heat - 85% of the energy in muscles can be released as heat to cool the body. When the body is cold, shivering will generate heat to warm it back up

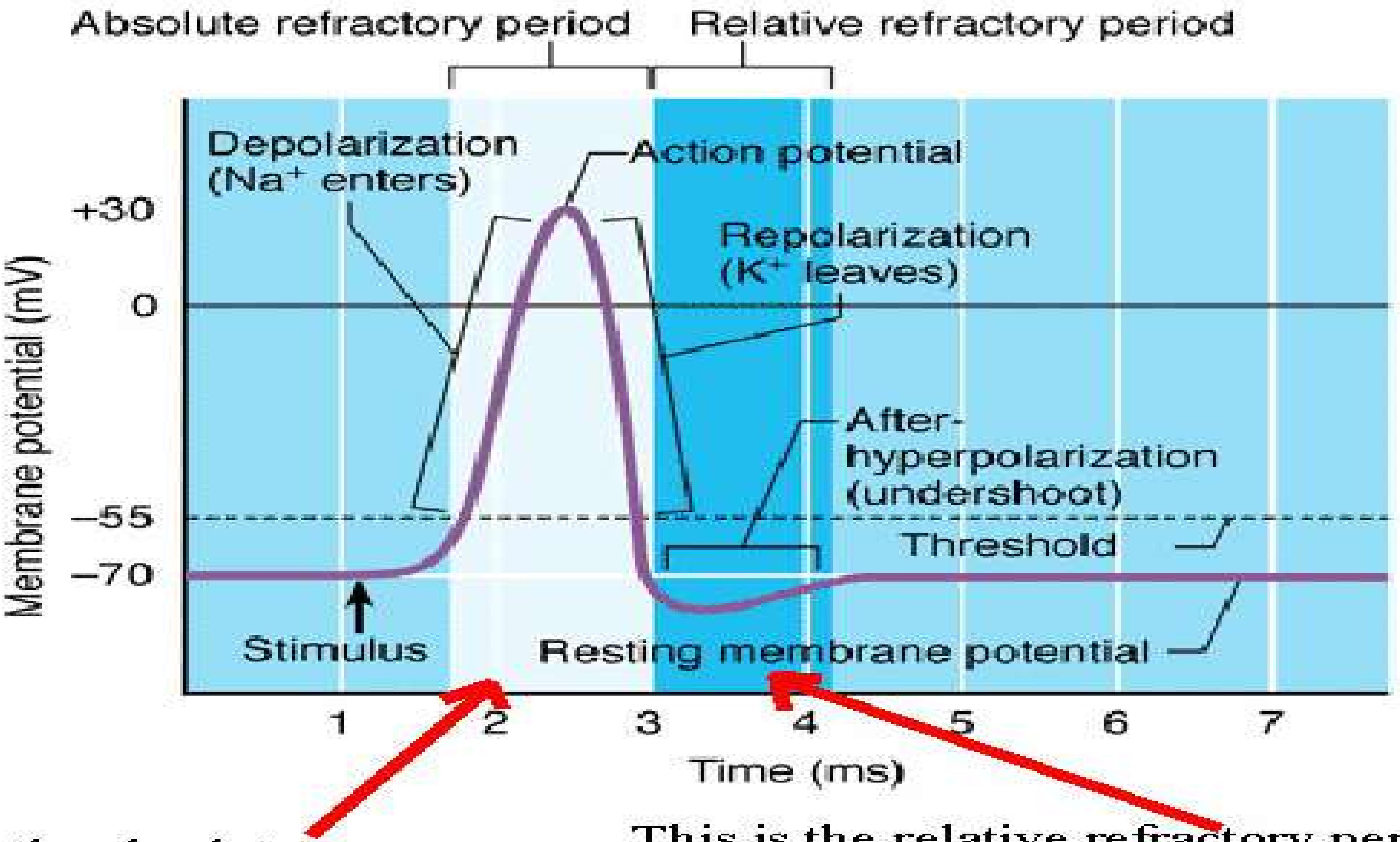


F. Contraction types - depends of stimulation frequency



1. Twitch - a brief contraction of all fibers in a motor unit from a single action potential
   - Latent period
   - Contraction period
   - Relaxation period
   - Refractory period

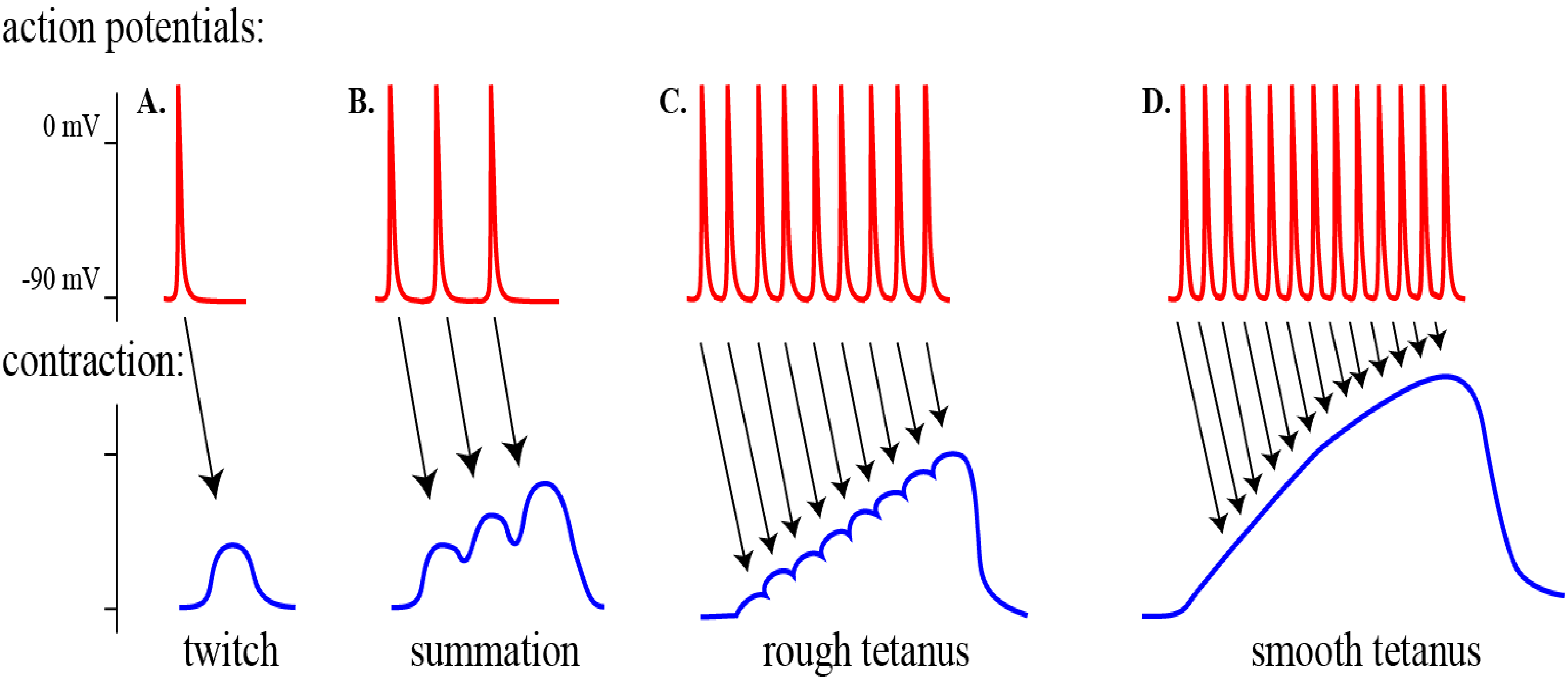




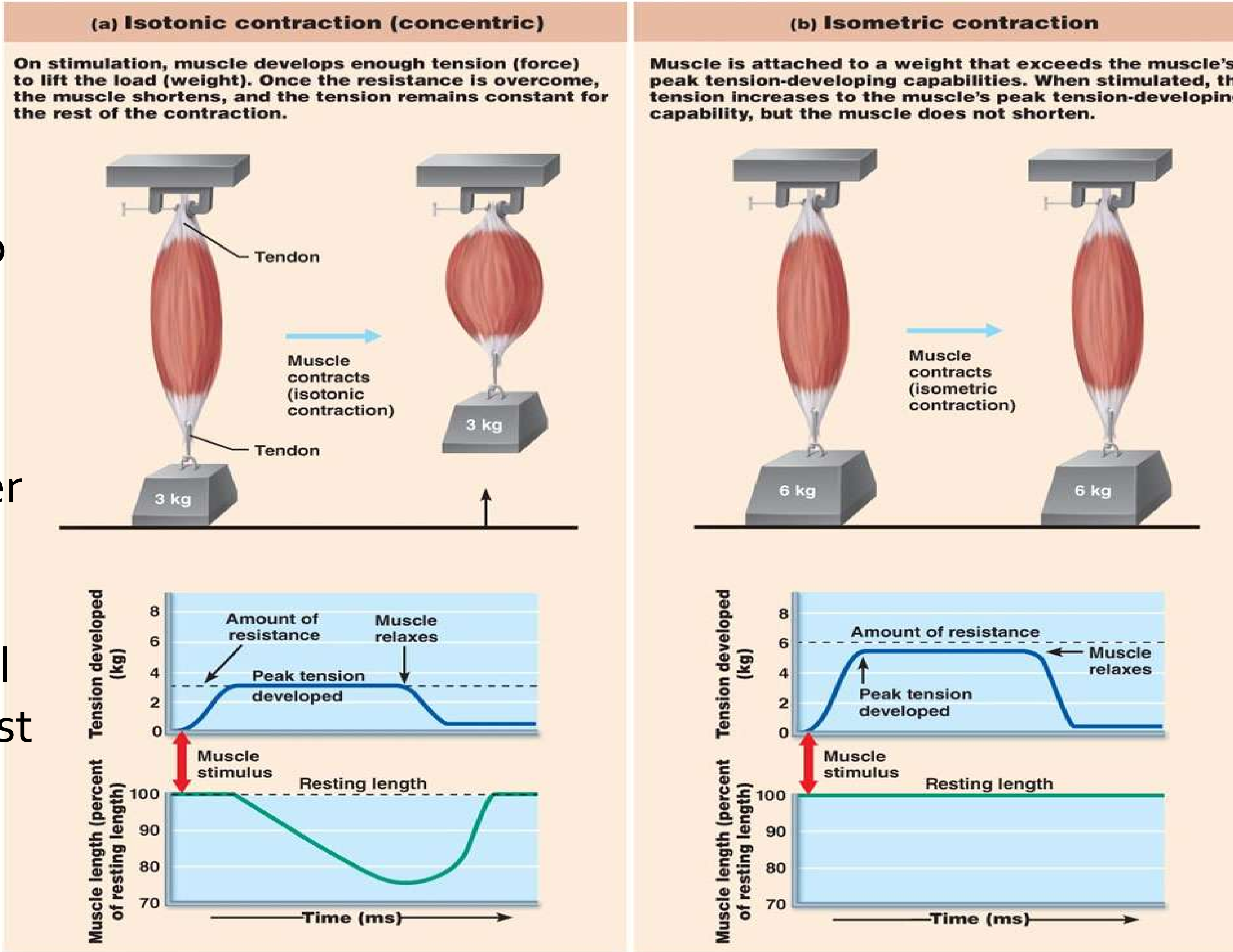
This is the absolute refractory period, when the muscle cannot be stimulated because it is depolarized.

This is the relative refractory period, when the membrane is hyperpolarized and requires a greater than normal stimulus.

2. Tetanus - a sustained contraction or short relaxation period. Comes from multiple action potentials arriving near the end of, or after the refractory period. Most voluntary movements are of this type



3. Isotonic – when a muscle contracts and pulls on another structure to create motion
4. Isometric - when a muscle contracts and pulls on another structure, but no motion occurs.
EX - Pushing with all your strength against a building



G. Muscle tone

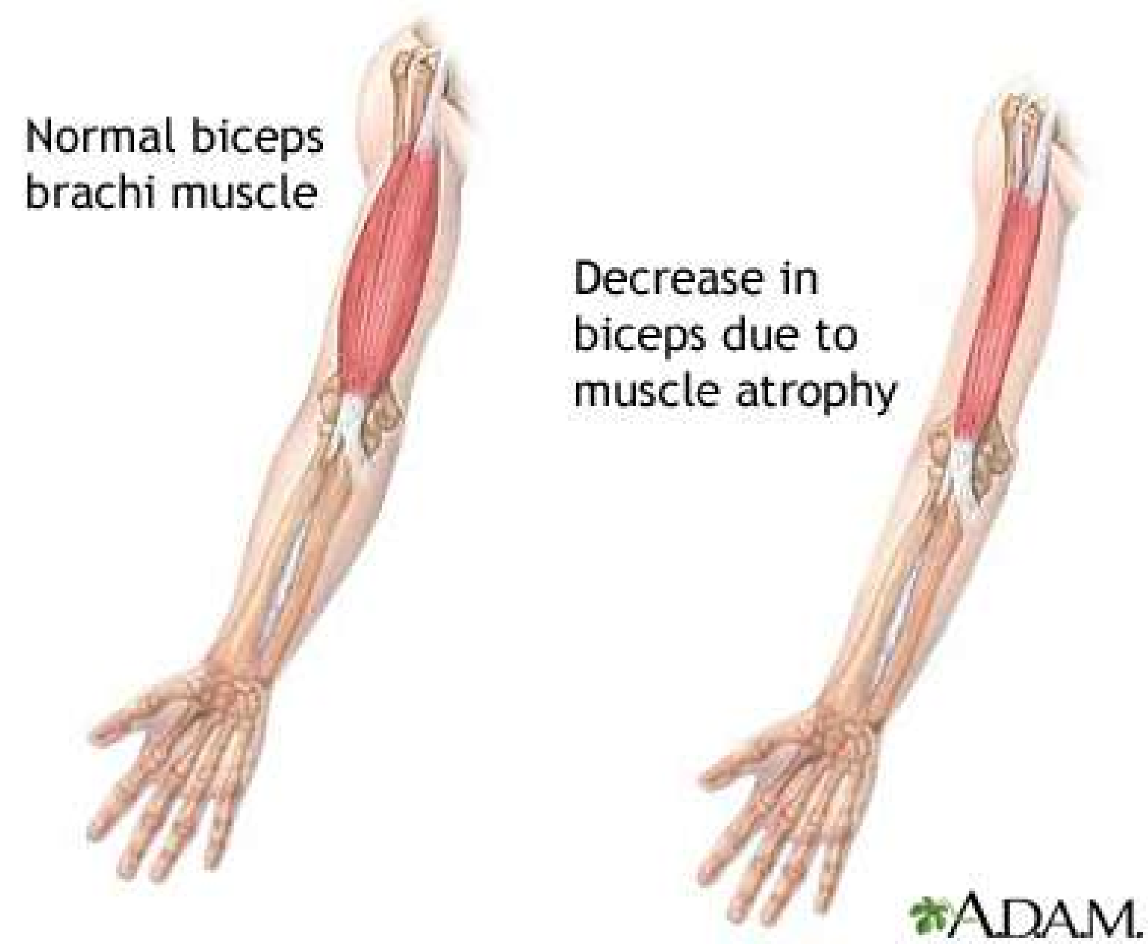
1. A sustained partial contraction, no motion. Some, but not many, muscle fibers are contracting at a time. EX - posture

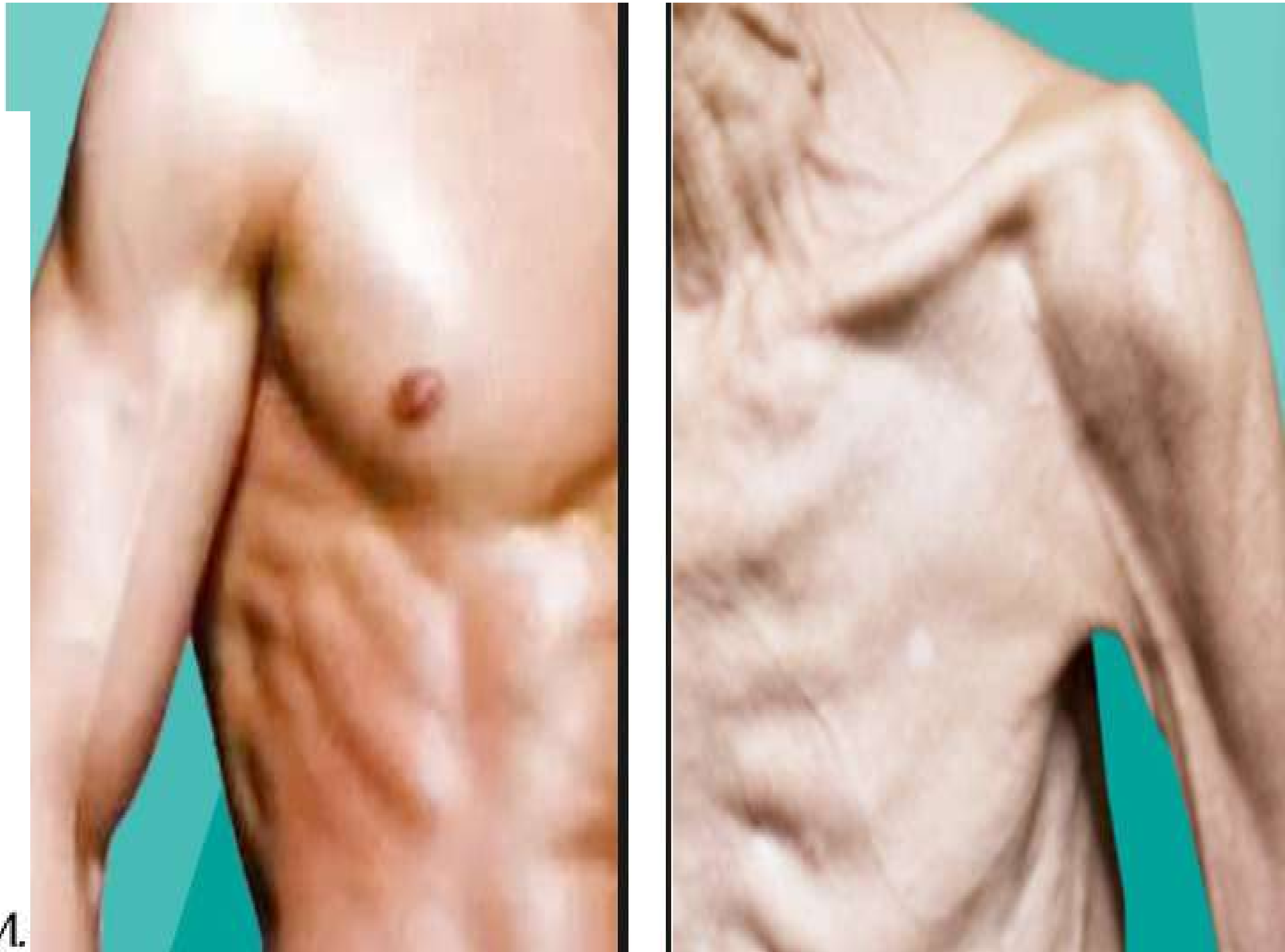
H. Abnormalities

1. Hypotonia - decreased muscle tone, flaccid
2. Hypertonia - increased muscle tone, rigid

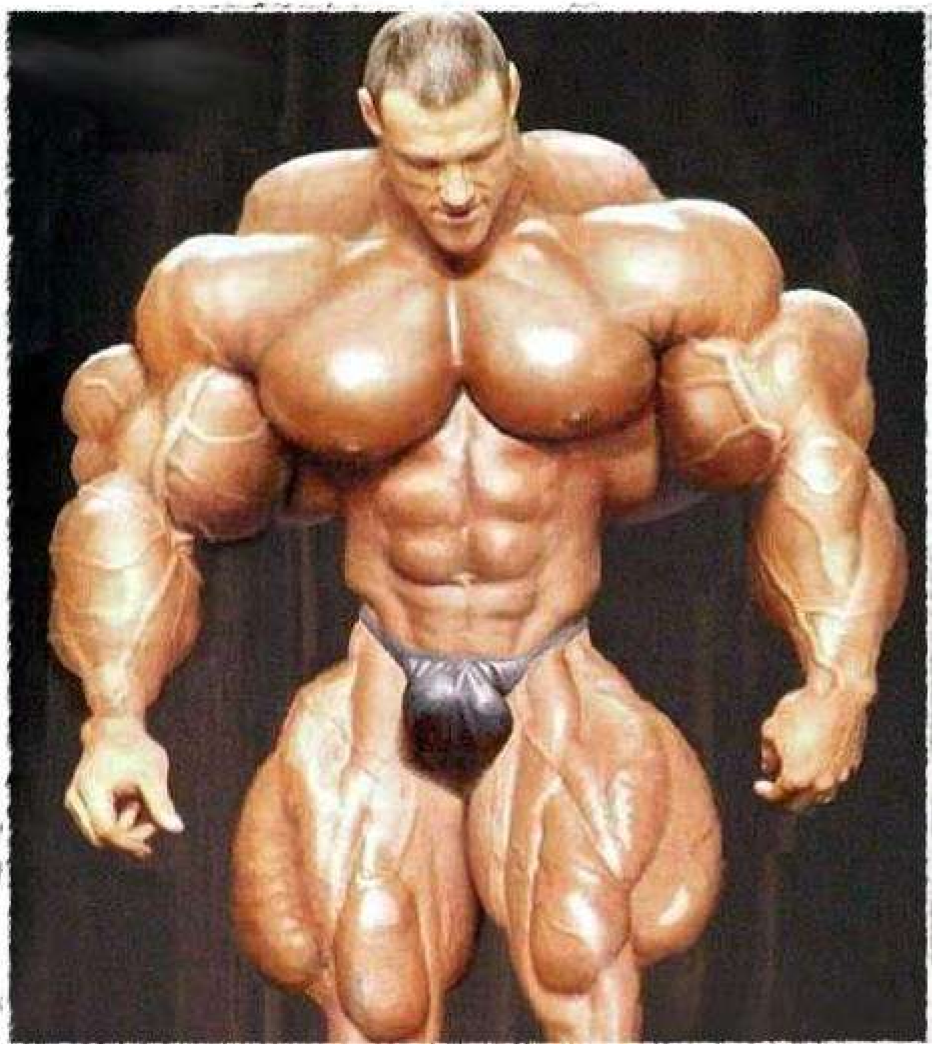

I. Muscular size

1. Muscular atrophy - wasting away of muscle tissue. Caused by inactivity. Complete atrophy can be caused by a loss of the nerve supply to the muscle. This will cause atrophy and the muscle tissue will be replaced by fibrous tissue. This is an irreplaceable loss





2. Muscular hypertrophy - increase in muscle size due to an increase in use. Muscles do not increase in number after birth. Therefore Pee Wee Herman can NEVER get as muscular as Mr. Universe no matter how much he lifts weights. Conversely, Mr Universe could never become Pee Wee Herman size, since he has more muscle fibers.

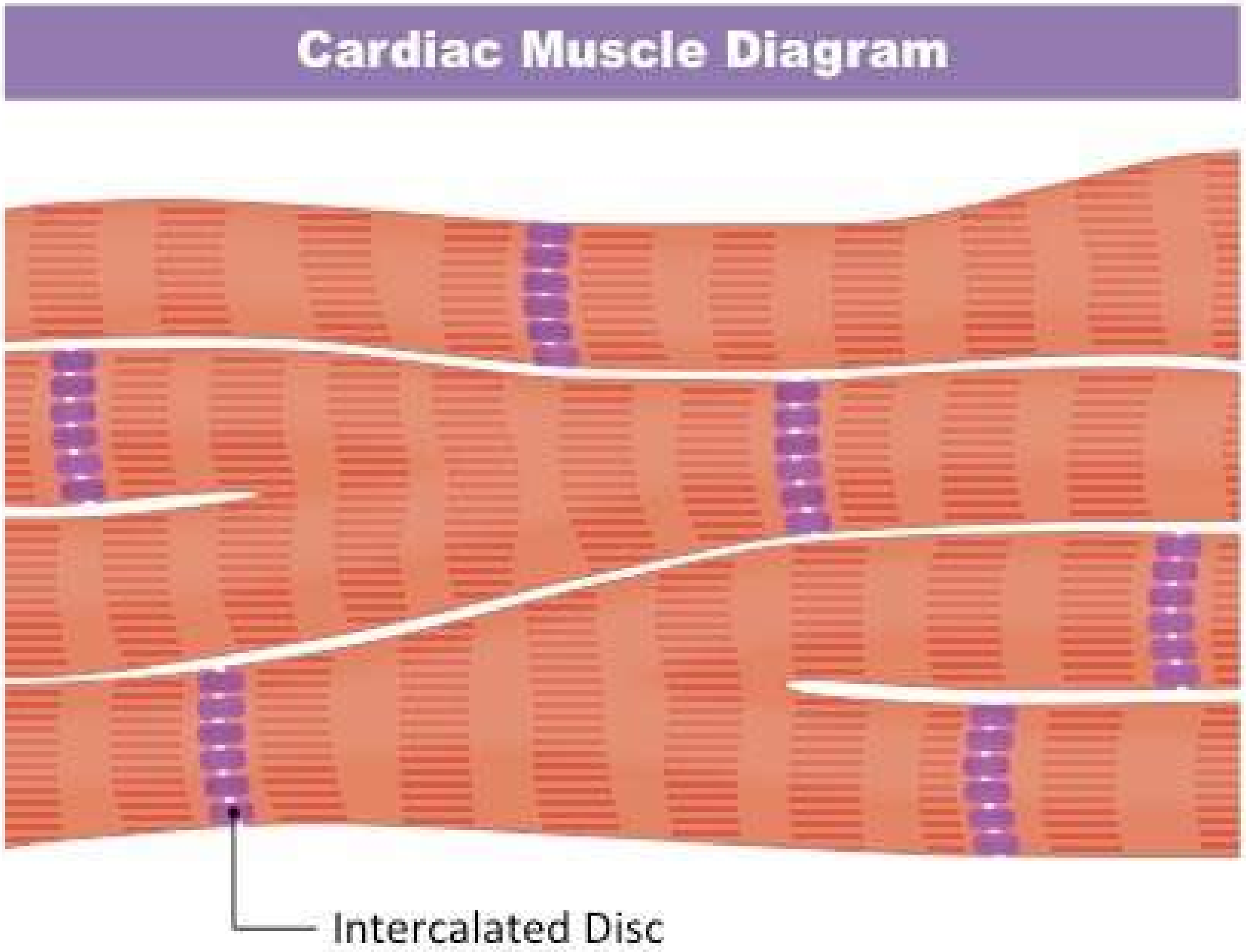


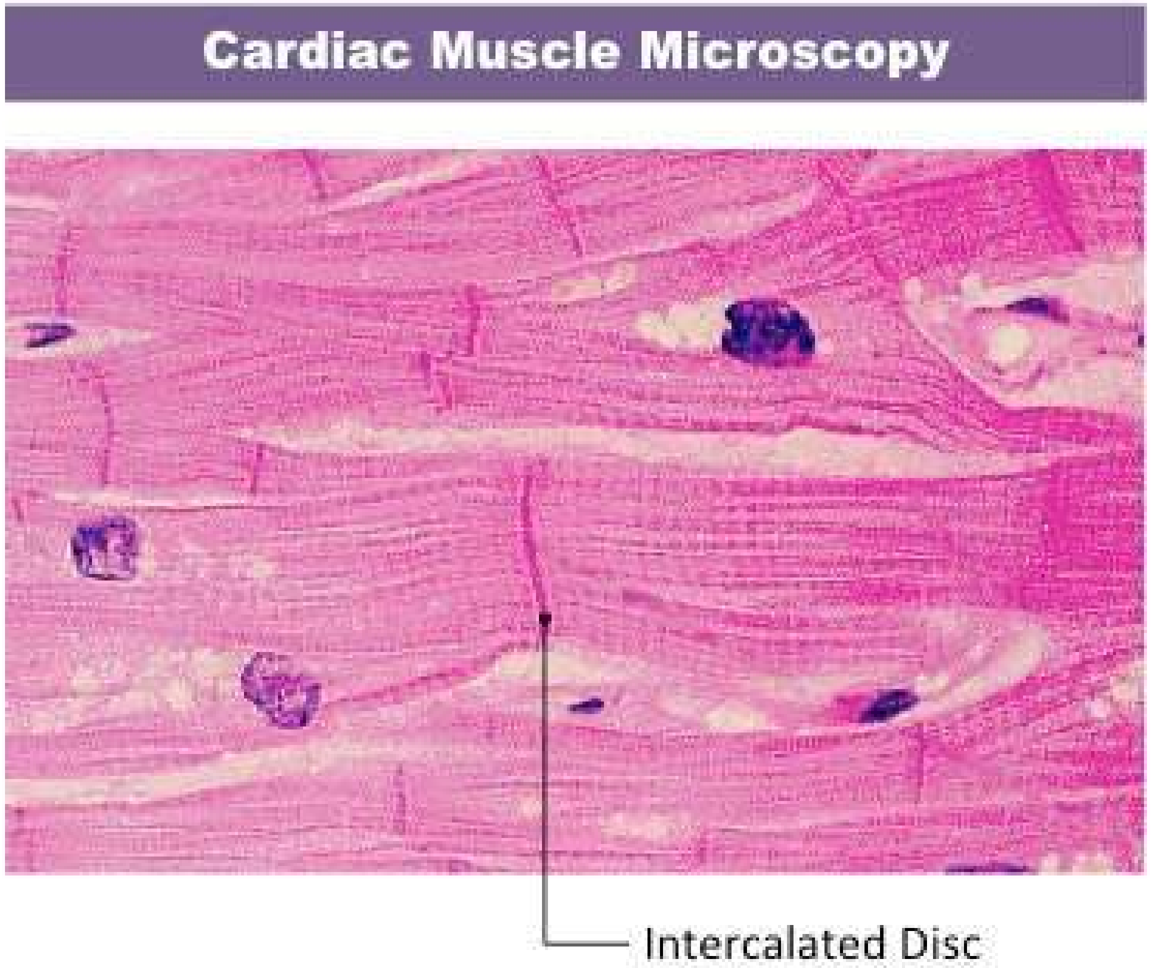
Cardiac Muscle

A. Characteristics

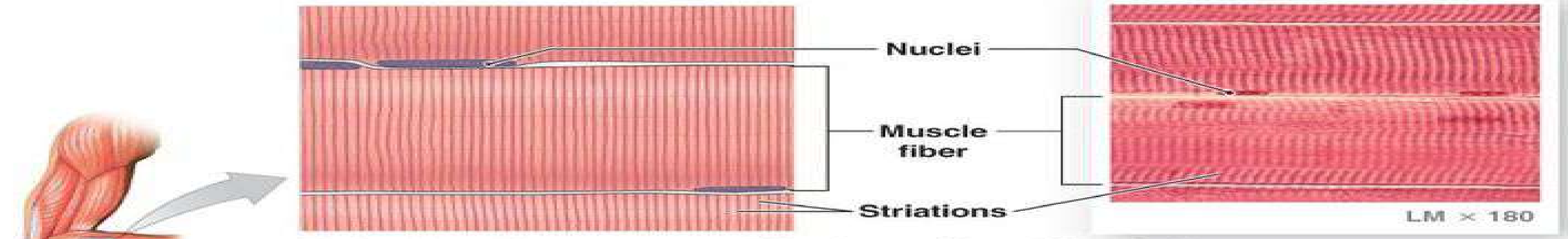
1. Involuntary 2. Branching 3. Striated striped

4. Shorter, thicker, more square shaped than skeletal

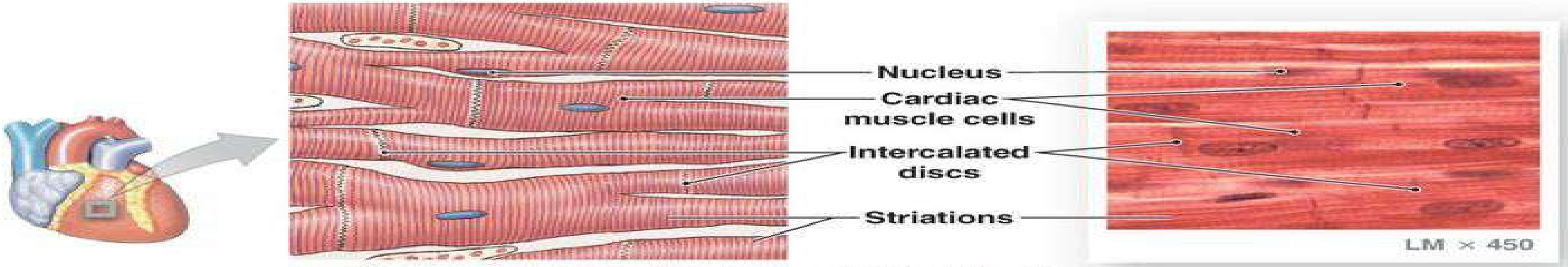




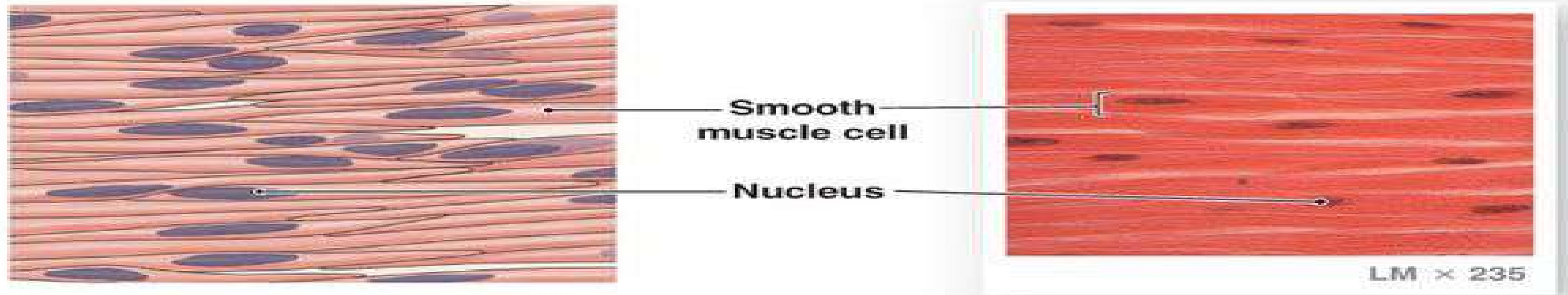
The structure and function of the three types of muscle tissue



Skeletal muscles move or stabilize the position of the skeleton; guard entrances and exits to the digestive, respiratory, and urinary tracts; generate heat; and protect internal organs.



Cardiac muscle moves blood and maintains blood pressure.



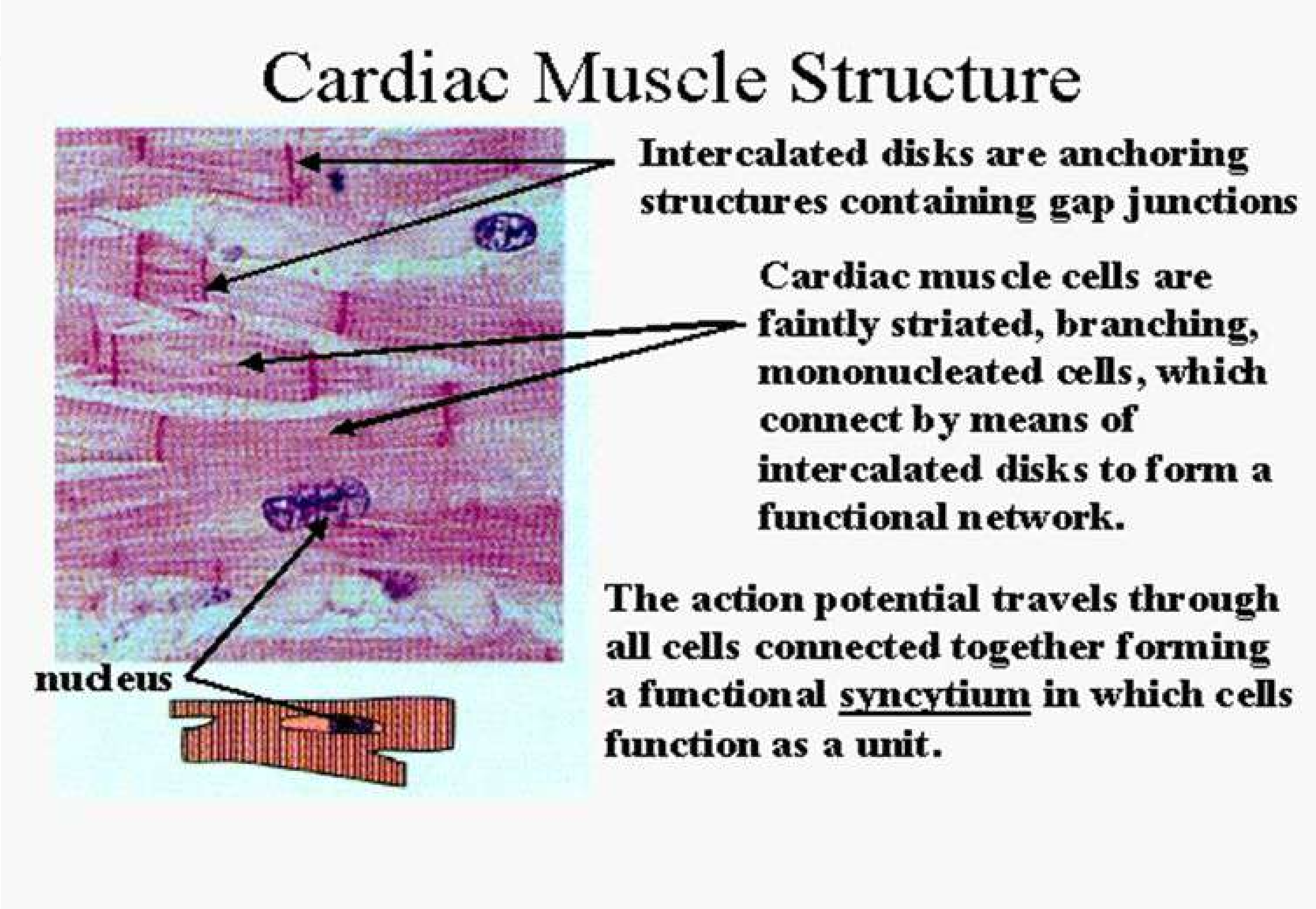
Smooth muscle moves food, urine, and reproductive tract secretions; controls diameter of respiratory passageways and regulates diameter of blood vessels.

B. Arrangement

1. The atria have one network (a branching and interconnection of muscle fibers), while the ventricles have a 2^{nd}.
2. Fibers within a network are connected by intercalated discs which have a gap junction to speed along impulses.

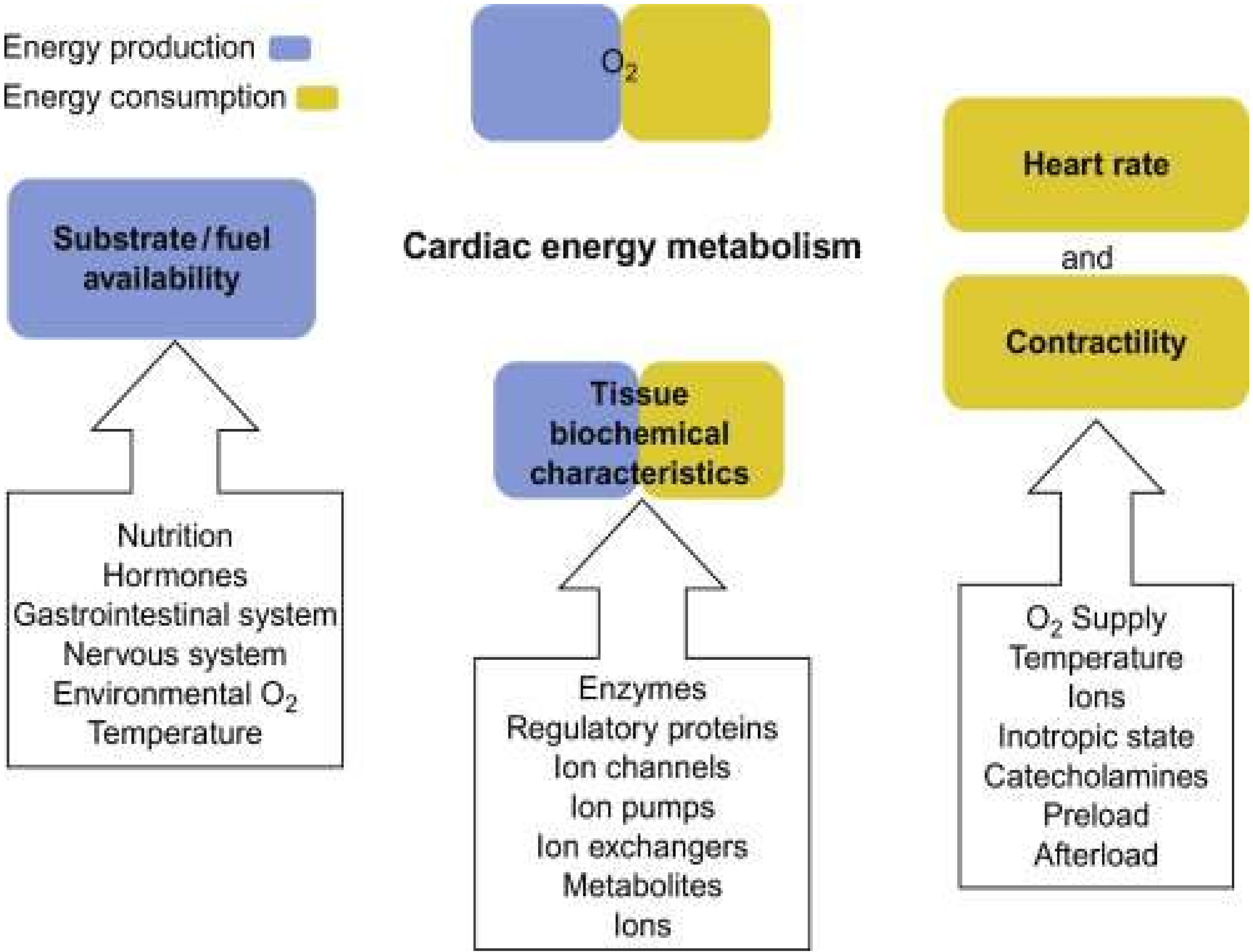
Cardiac muscle

- Forms 2 networks atrial and ventricular.
- Fibers are connected by intercalated disks.



C. Differences

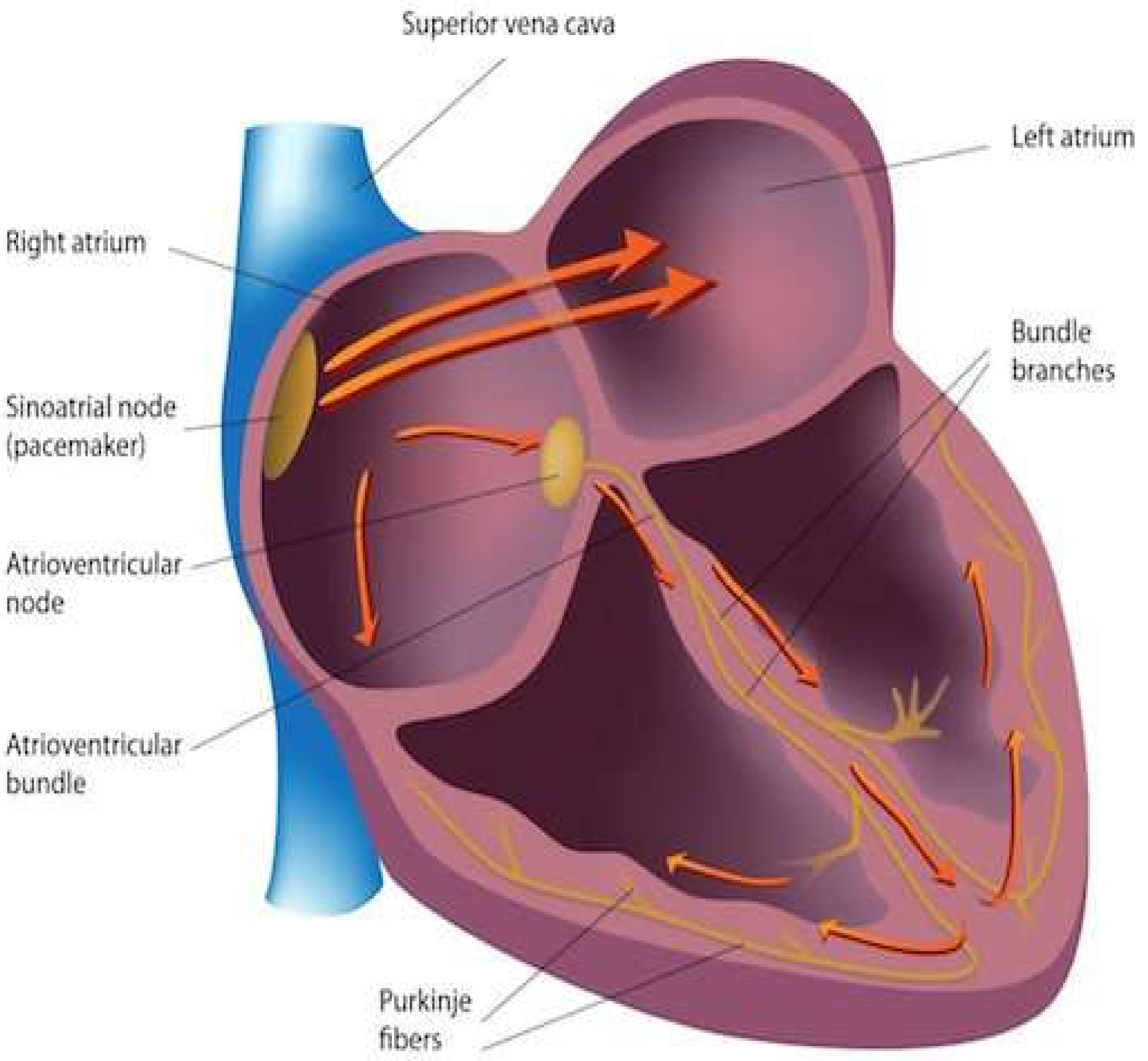
1. Cardiac tissue beats continuously, we hope, so needs a constant energy supply

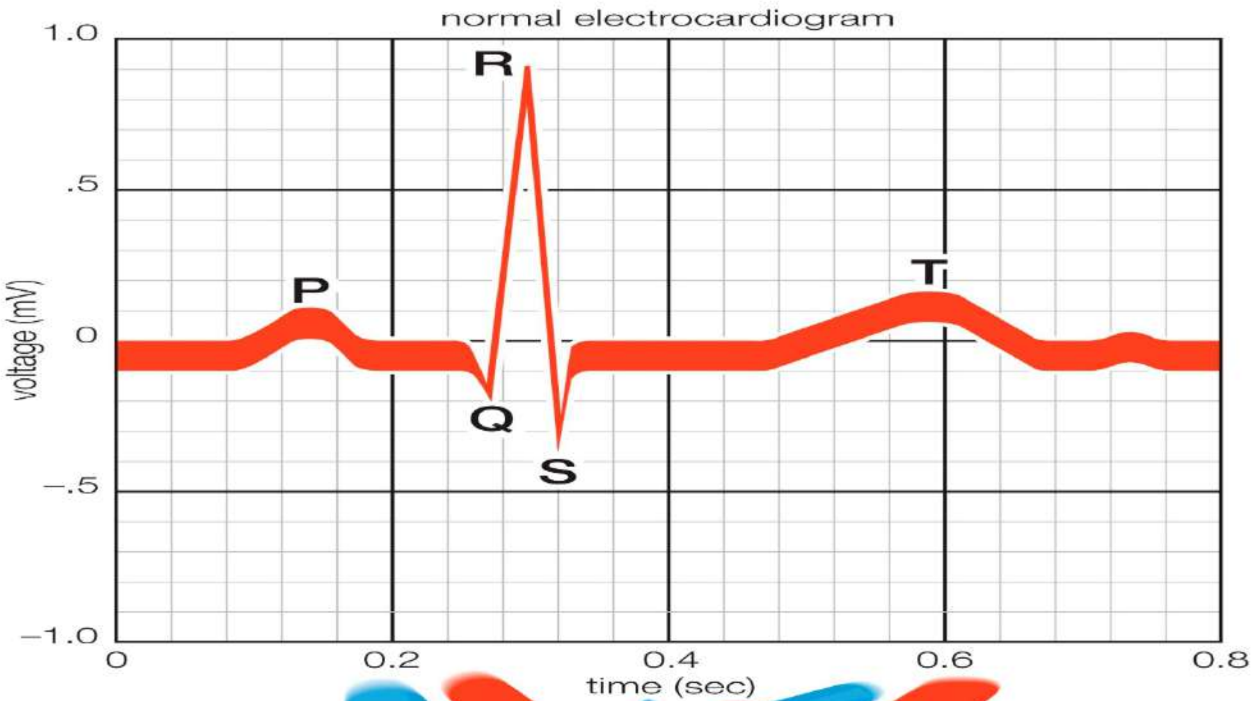


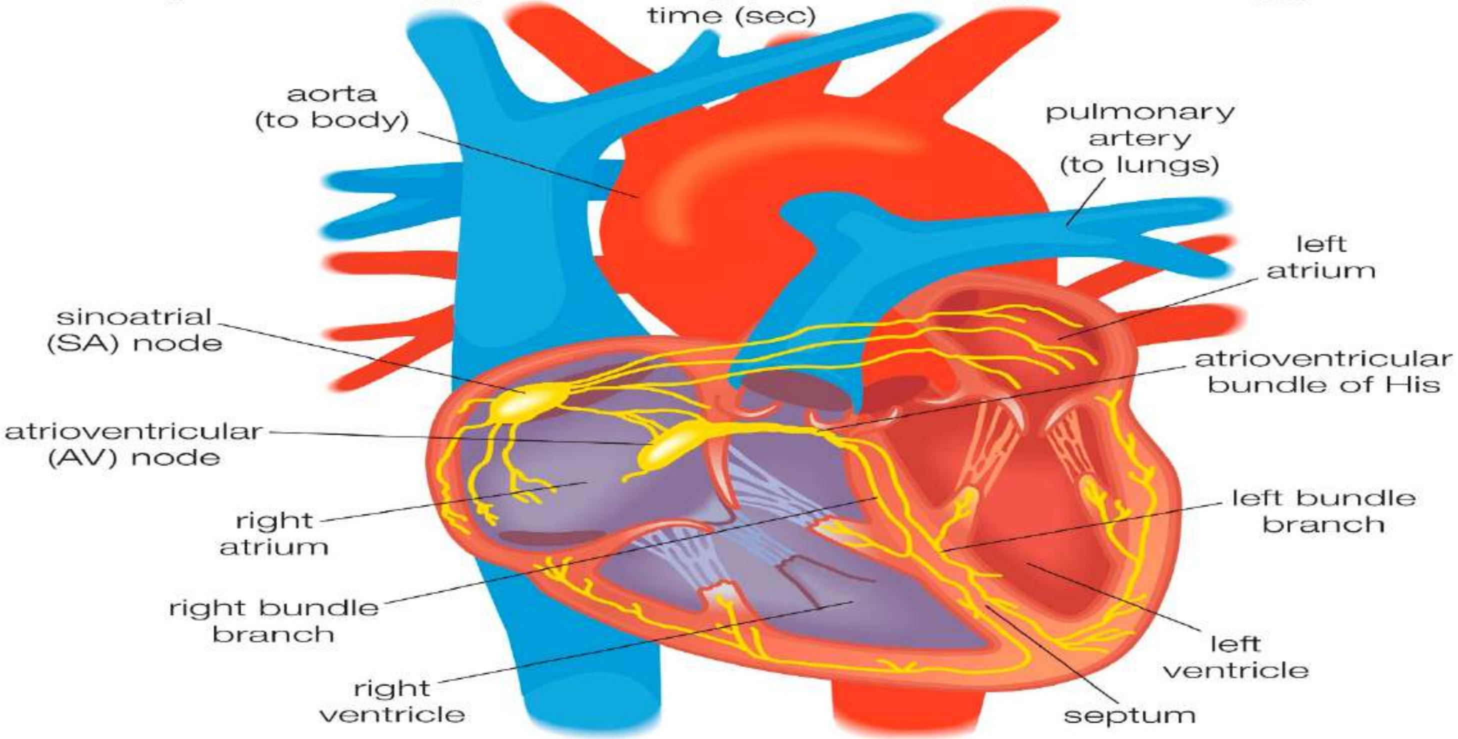
C. Differences

1. *Cardiac tissue beats continuously, we hope, so needs a constant energy supply*

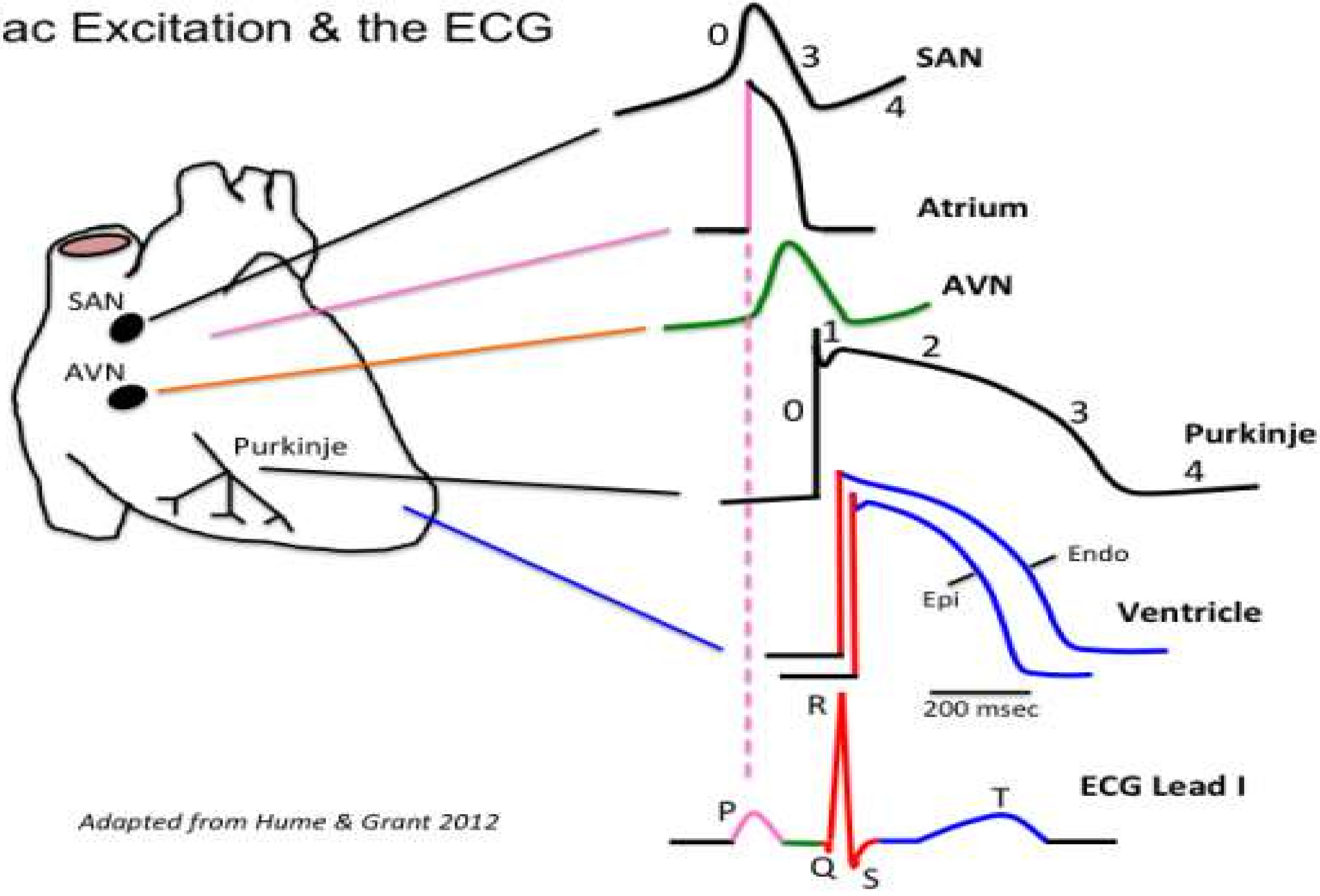
2. Cardiac tissue causes its own contractions, its own nervous impulses, in the pacemaker. This is called autorhythmicity .




normal electrocardiogram
1.0
.5
0
–.5
–1.0
voltage (mV)
P
Q
R
S
T
0
0.2
0.4
0.6
0.8
time (sec)

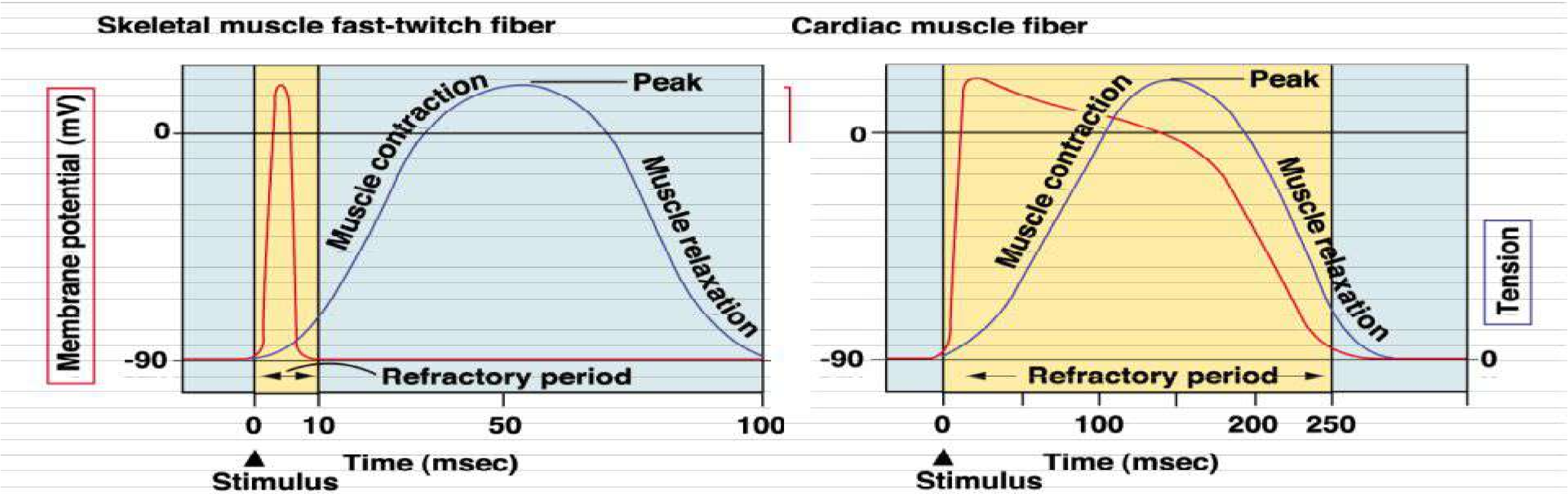

aorta (to body)
pulmonary artery (to lungs)
left atrium
sinoatrial (SA) node
atrioventricular bundle of His
atrioventricular (AV) node
right atrium
left bundle branch
right bundle branch
left ventricle
right ventricle
septum

Cardiac Excitation & the ECG



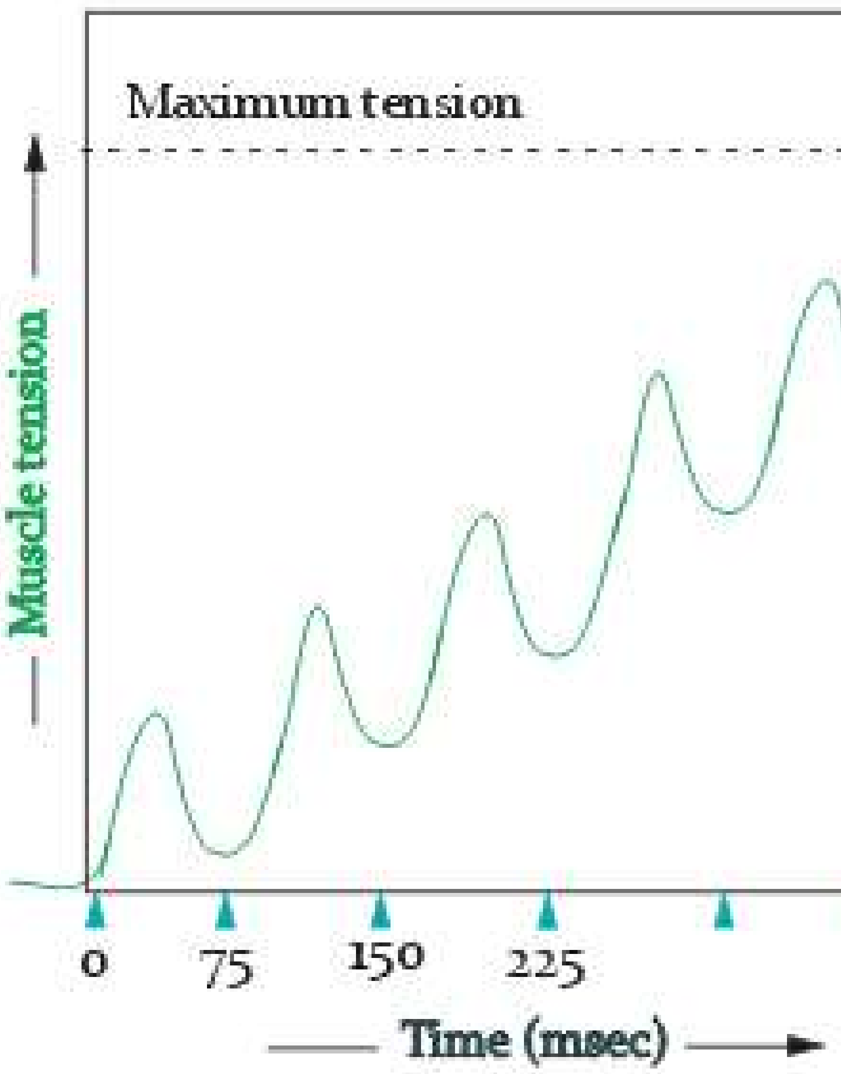
Adapted from Hume & Grant 2012

3. Cardiac tissue has a long refractory period. This reduces the possibility of tetanus - a stopped, contracted heart.

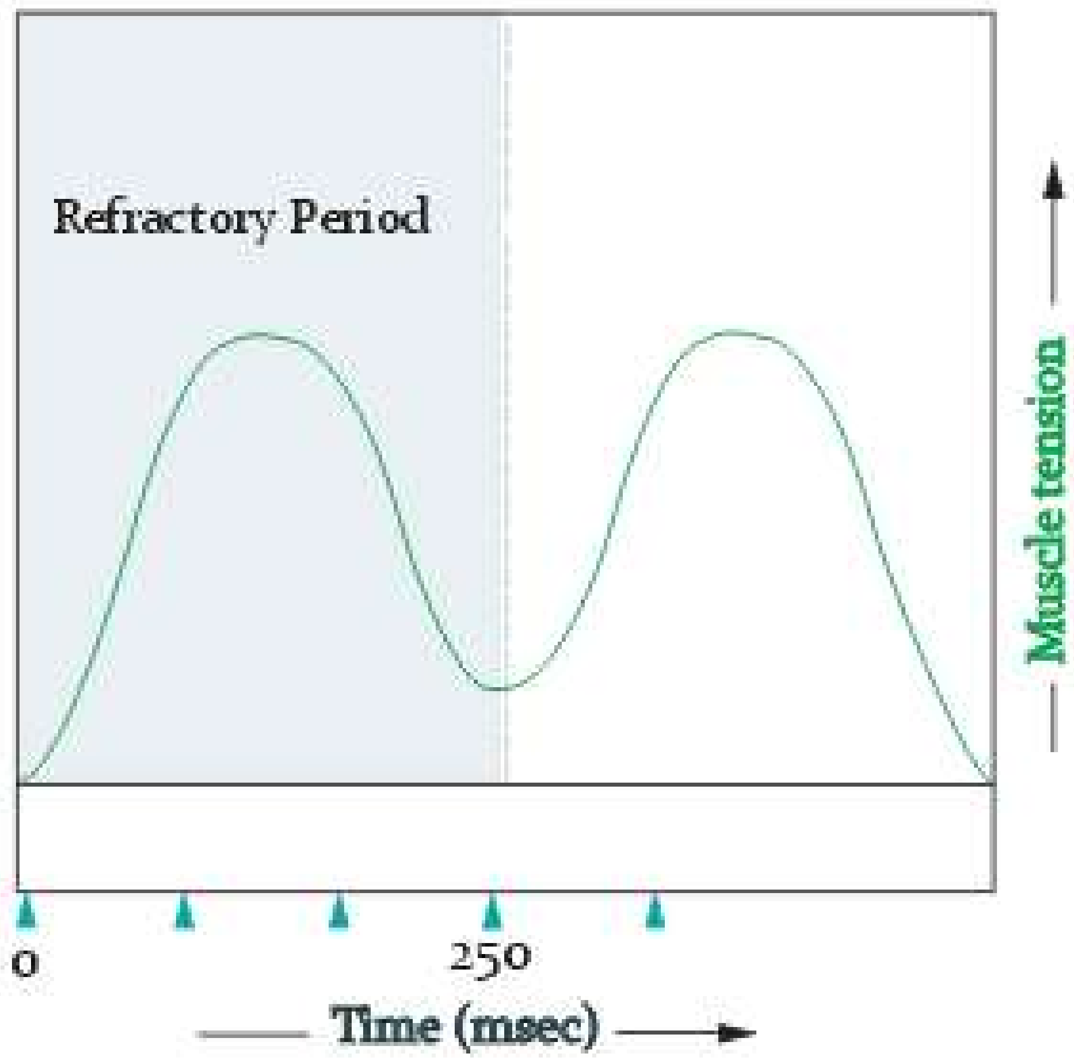


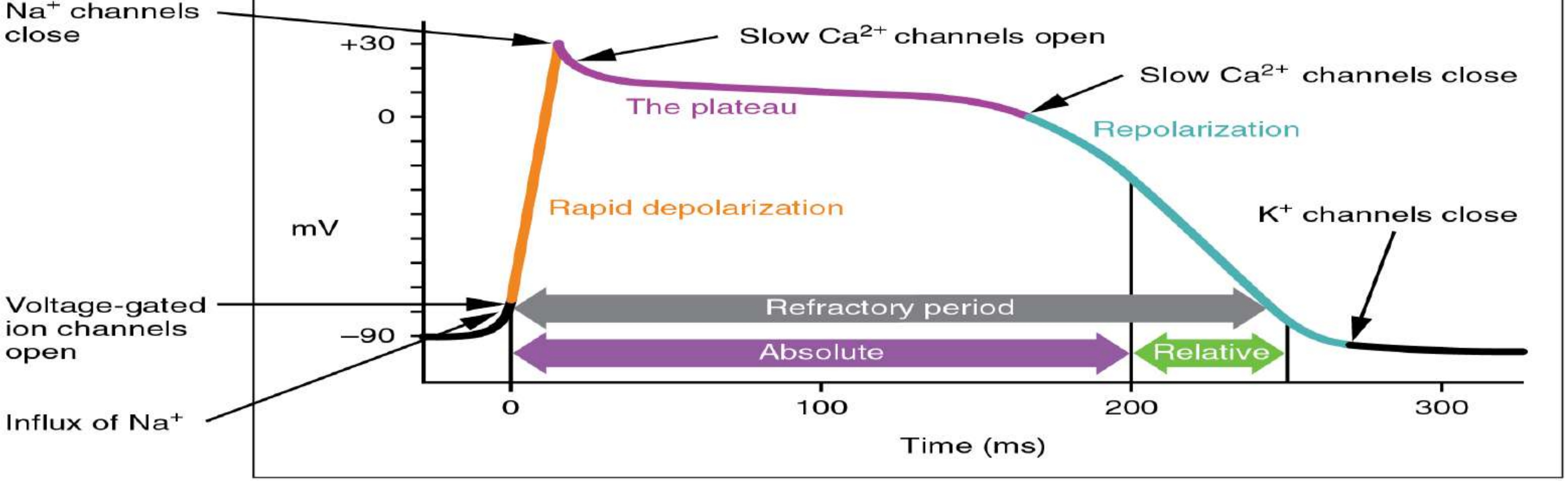
- The refractory period is short in skeletal muscle, but very long in cardiac muscle – 250 msec
- This means that skeletal muscle can undergo summation and tetanus, via repeated stimulation
- Cardiac muscle CAN NOT sum action potentials or contractions and can't be tetanized

Fast repititive stimulation of skeletal muscles results in a sustained contration called tetanus



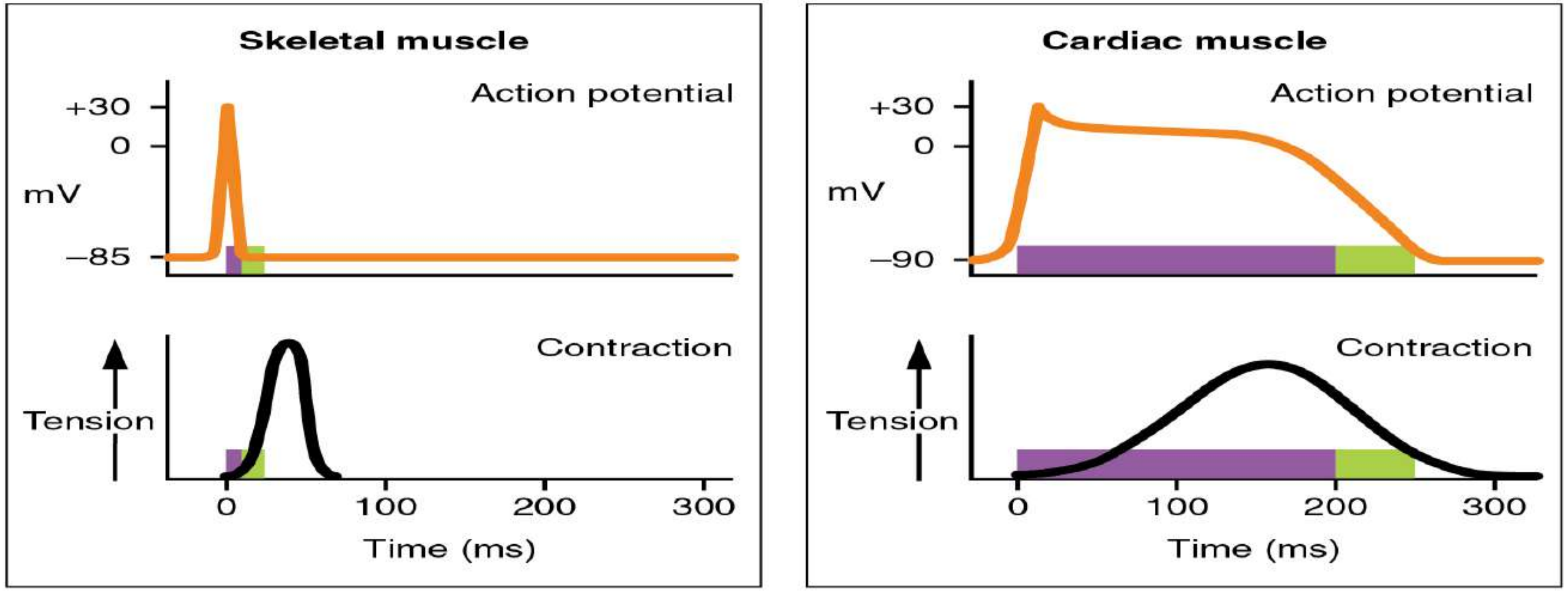
Long refractory periods in cardiac muscles prevents tetanus





Na+ channels close
Slow Ca2+ channels open
Slow Ca2+ channels close
+30
0
The plateau
Repolarization
Rapid depolarization
mV
K+ channels close
Voltage-gated ion channels open
Refractory period
–90
Absolute
Relative
Influx of Na+
0
100
200
300
Time (ms)

(a)



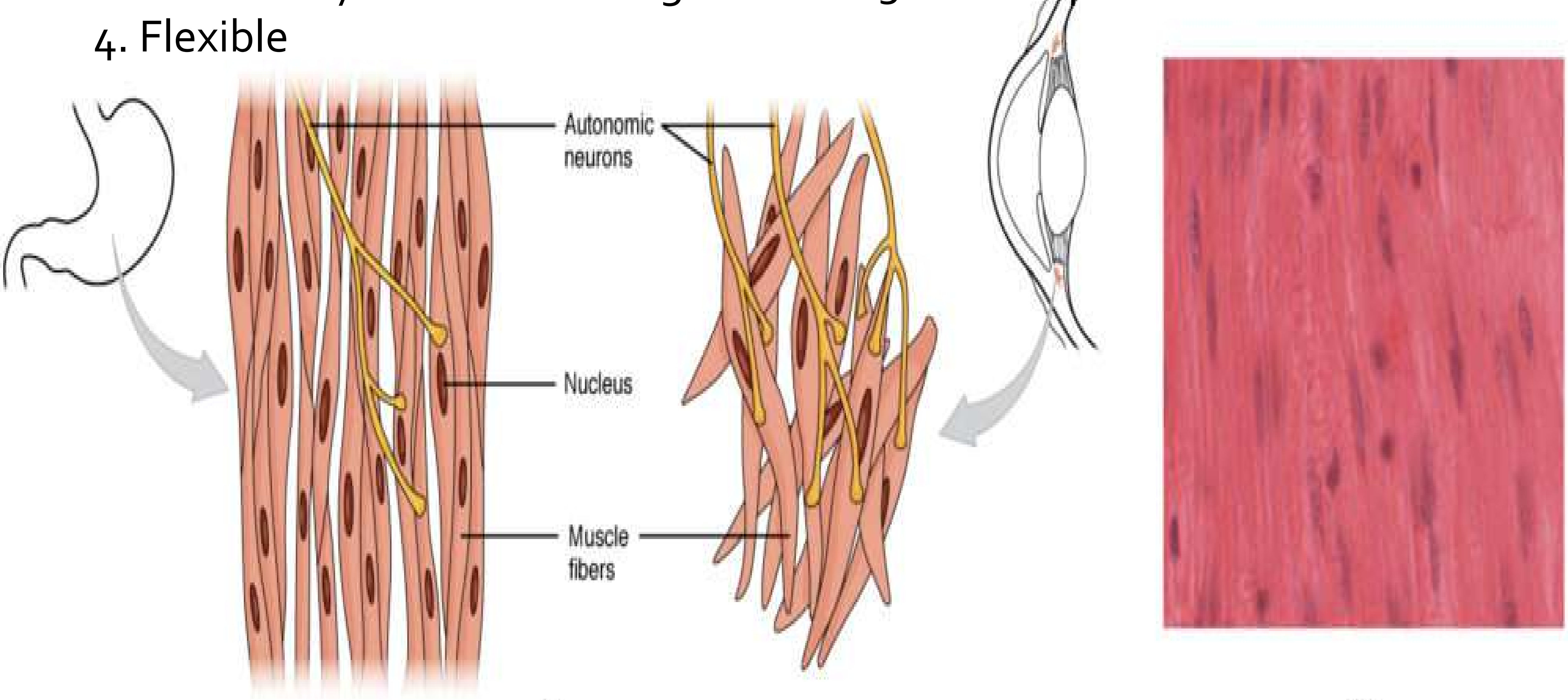
Skeletal muscle
Action potential
+30
0
mV
–85
Contraction
Tension
0
100
200
300
Time (ms)
Cardiac muscle
Action potential
+30
0
mV
–90
Contraction
Tension
0
100
200
300
Time (ms)

(b)

Smooth Muscle

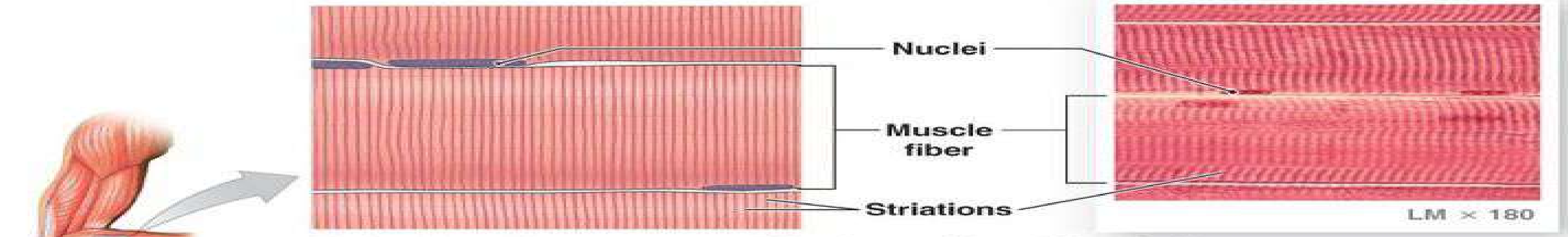
A. Characteristics

1. Involuntary 2. Found in organs 3. Not striped
4. Flexible

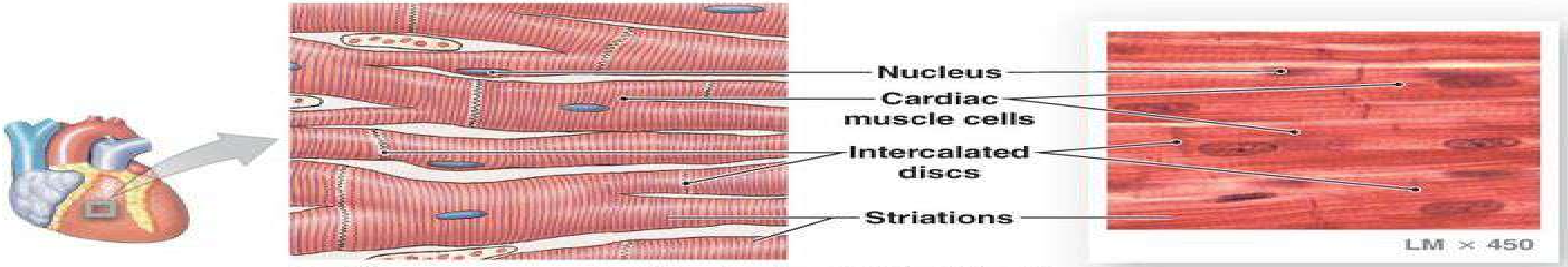


(a) (b)

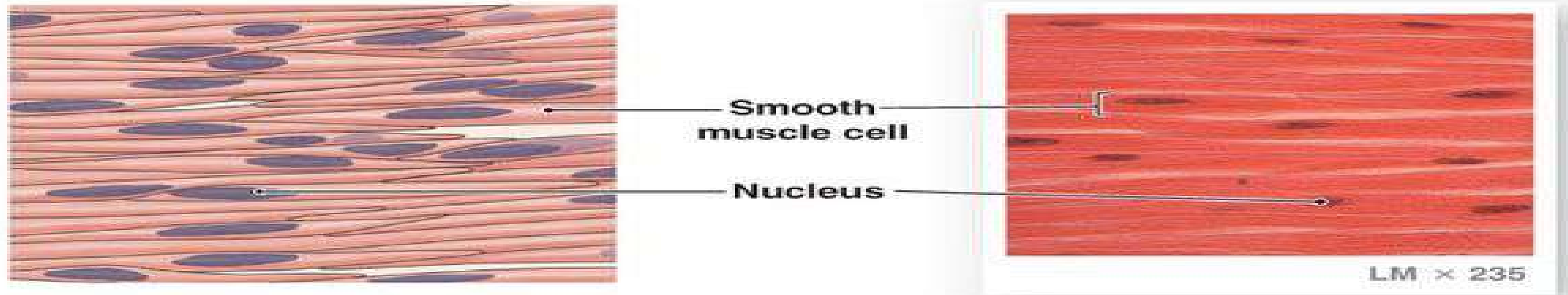
The structure and function of the three types of muscle tissue



Skeletal muscles move or stabilize the position of the skeleton; guard entrances and exits to the digestive, respiratory, and urinary tracts; generate heat; and protect internal organs.



Cardiac muscle moves blood and maintains blood pressure.



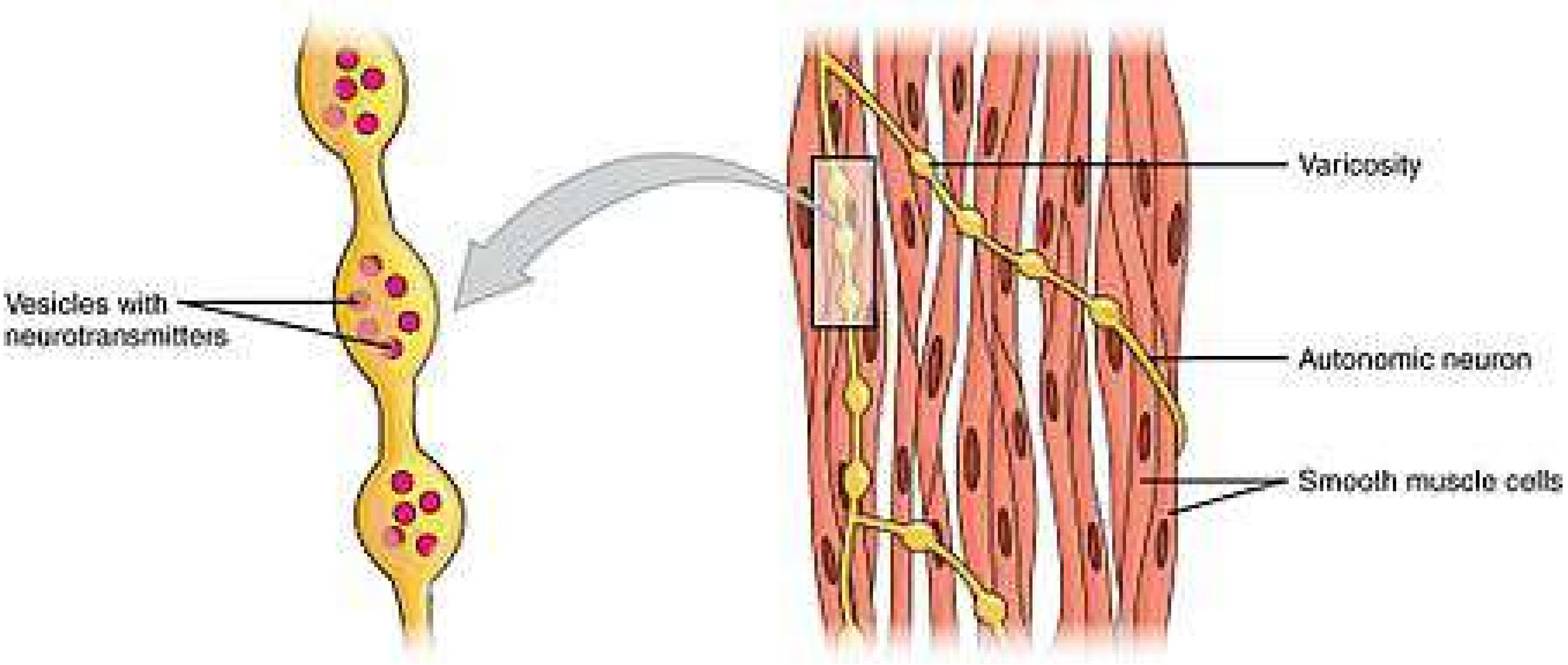
Smooth muscle moves food, urine, and reproductive tract secretions; controls diameter of respiratory passageways and regulates diameter of blood vessels.

B. Types

1. Visceral

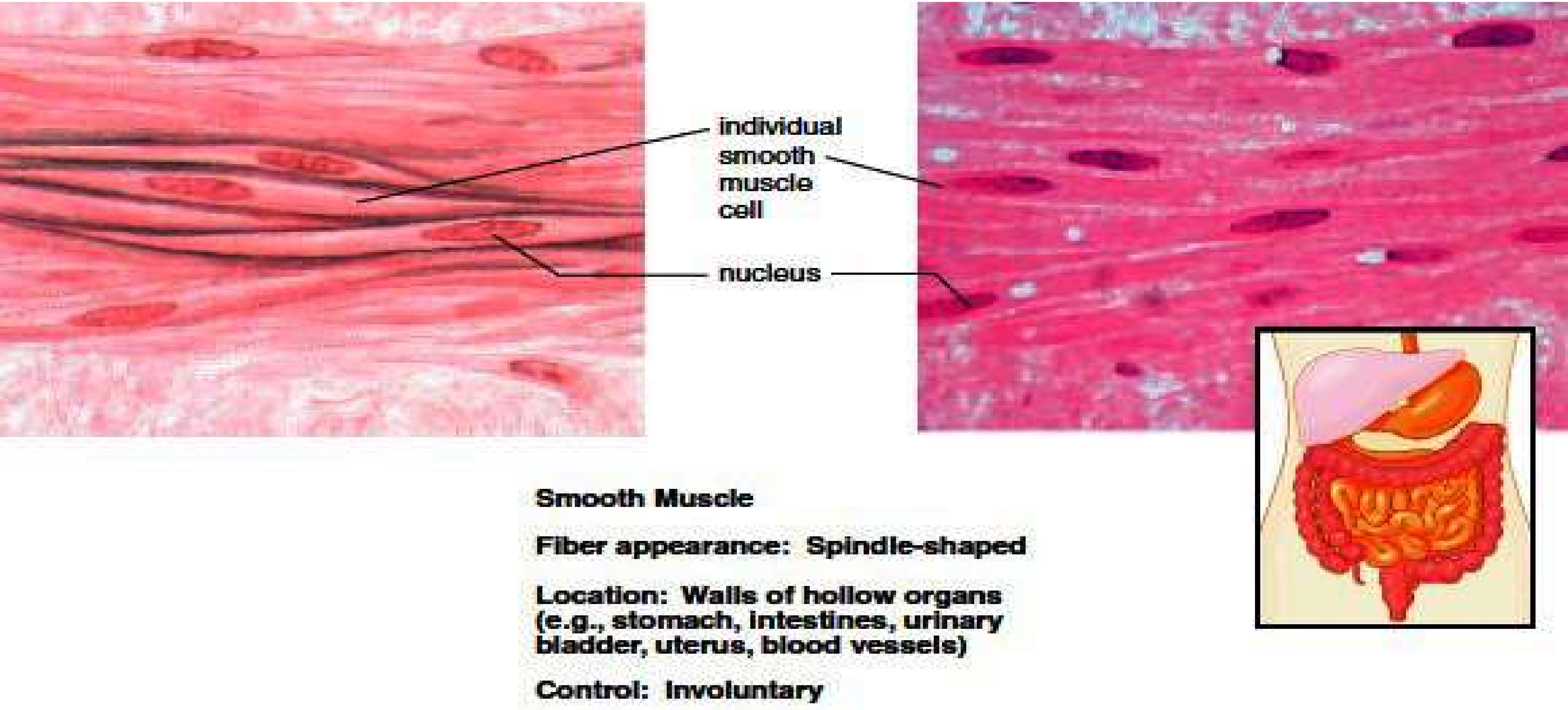
a. Large sheets that form a continuous network of muscle

b. The whole sheet responds to a single impulse, not singly like skeletal muscle https://www.youtube.com/watch?v=o18UycWRsaA



c. Found in small blood vessels, stomach, intestines, uterus, bladder.

d. More common type of smooth muscle

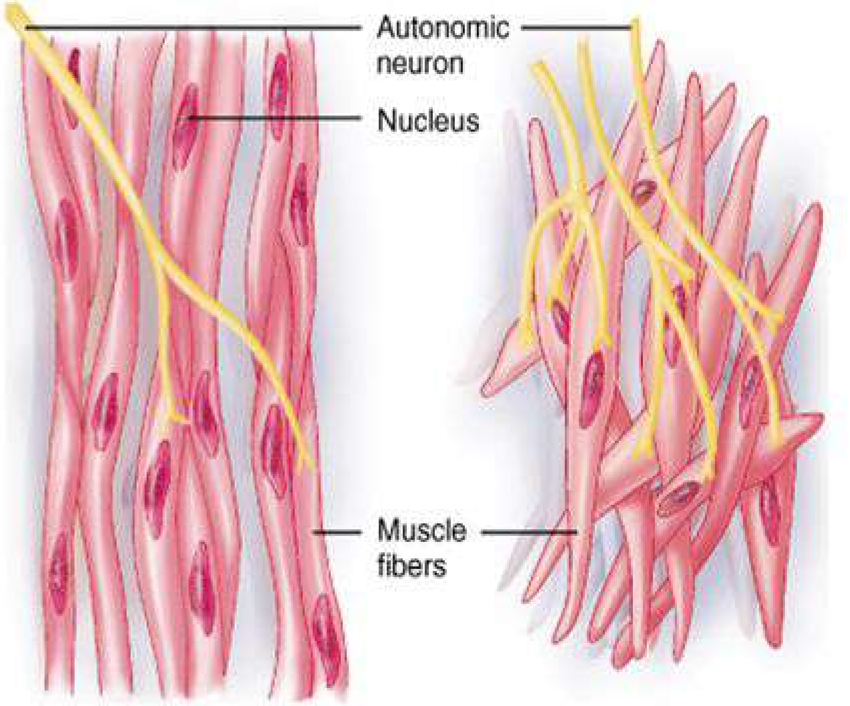


Two Types of Smooth Muscle

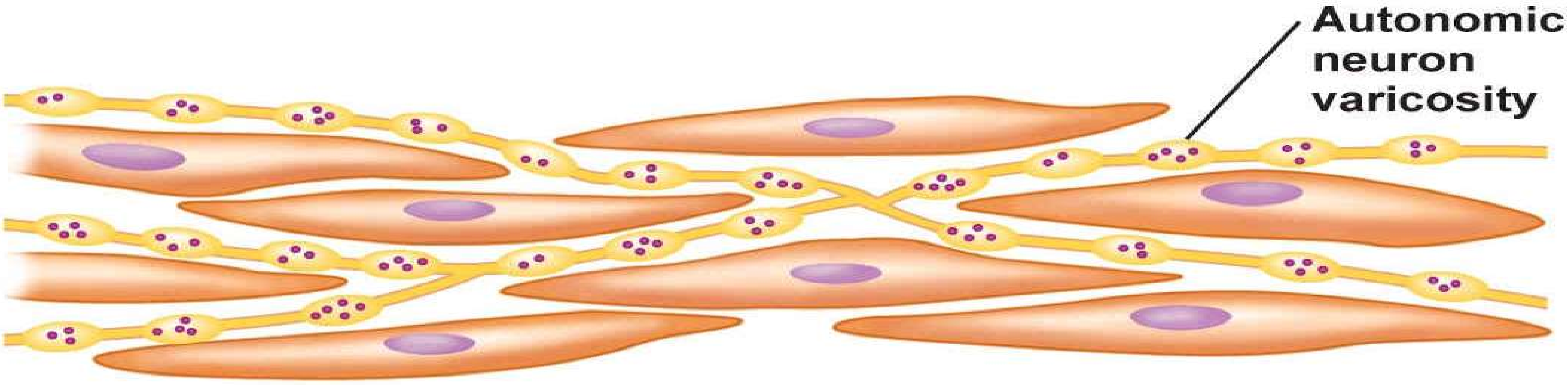
2. Multiunit smooth muscle
   a. Acts like skeletal with individual fibers contracting individually.
   b. Found in large blood vessels, large lung airways, arrector pili muscles (hair)

https://www.youtube.com/watch?v=EkZTxbnALoE

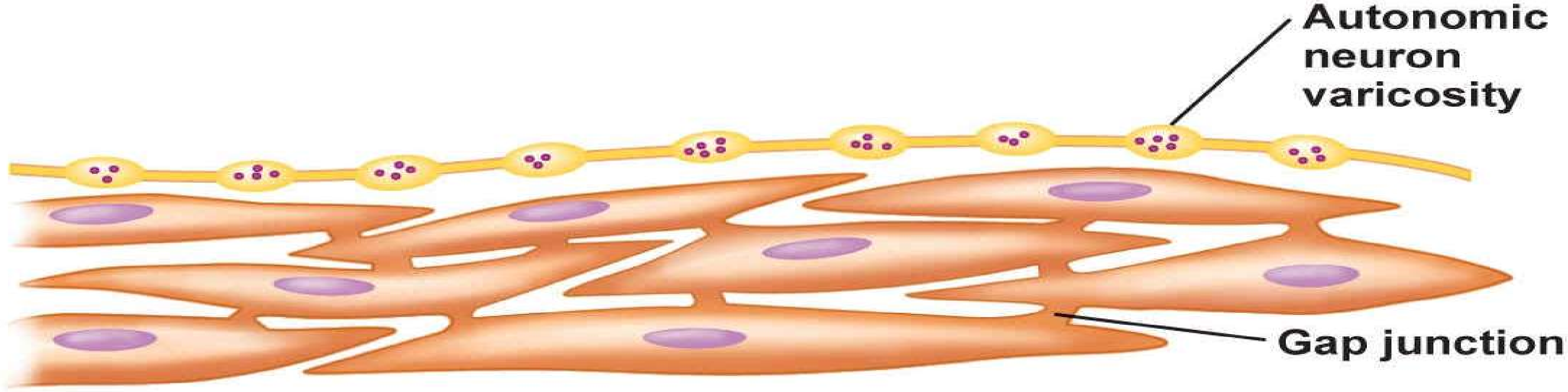
- **Visceral (single-unit)**
  - in the walls of hollow viscera & small BV
  - autorhythmic
  - gap junctions cause fibers to contract in unison
- **Multiunit**
  - individual fibers with own motor neuron ending
  - found in large arteries, large airways, arrector pili muscles,iris & ciliary body



(a) Visceral (single-unit) smooth muscle tissue
(b) Multiunit smooth muscle tissue



(a) Multi-unit smooth muscle



(b) Single-unit smooth muscle

Control (cont.)

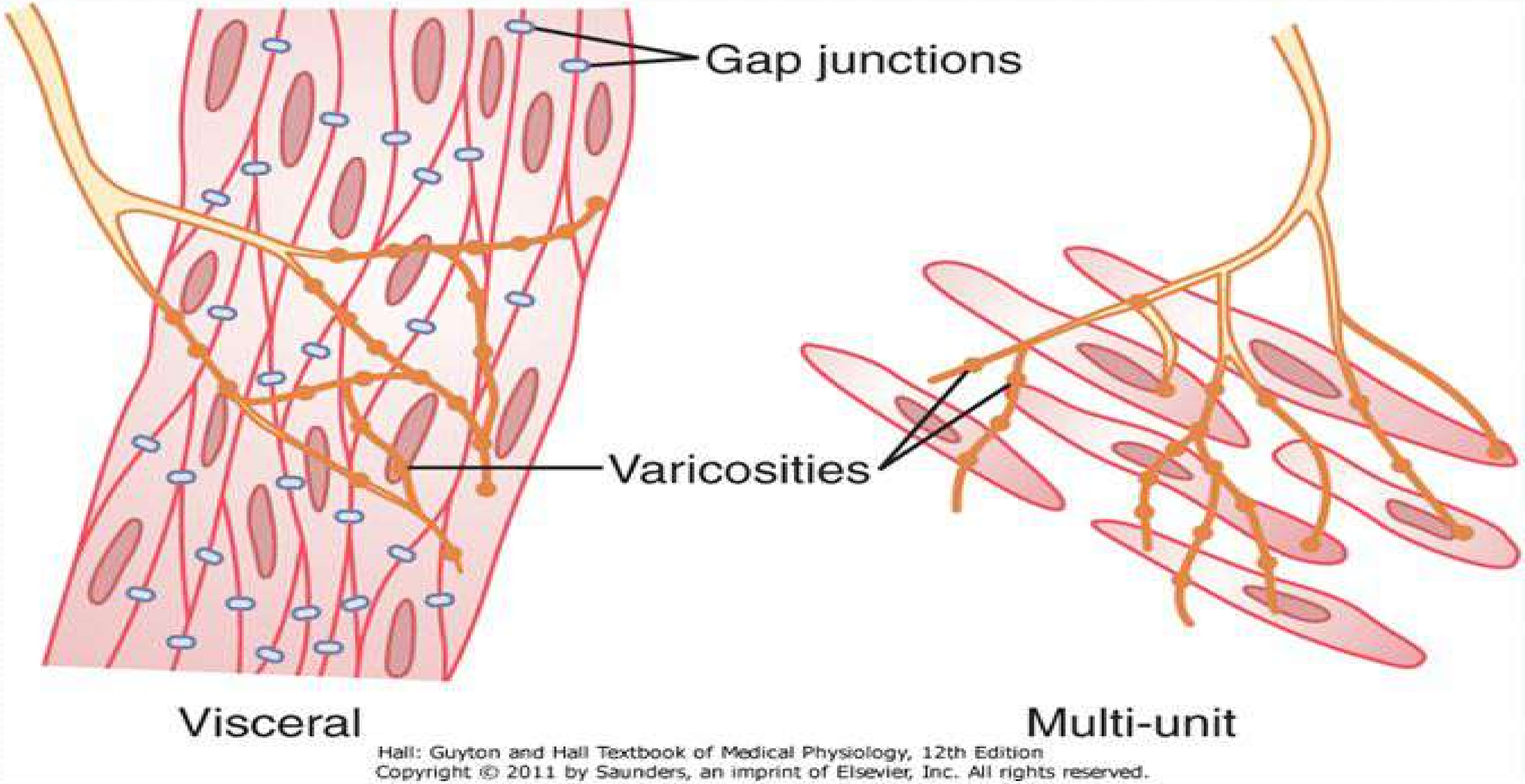
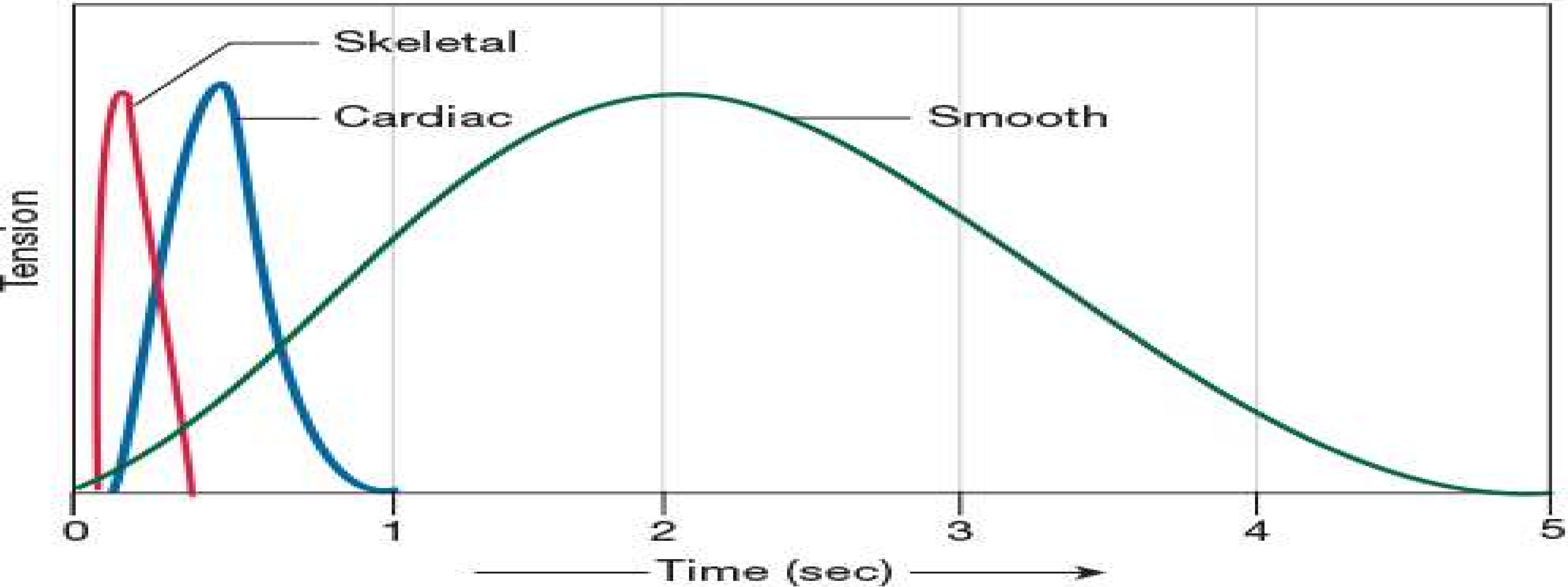


Fig. 8.4 Innervation of Smooth Muscle

C. Differences

1. Longer contractile periods than skeletal
2. Can sustain a contraction longer = more tone

Smooth muscles are the slowest to contract and to relax.



C. Differences

1. *Longer contractile periods than skeletal*
2. *Can sustain a contraction longer = more tone*
3. Can be stimulated by nervous impulses, hormones, pH, gas levels, temperature.
4. More extensible

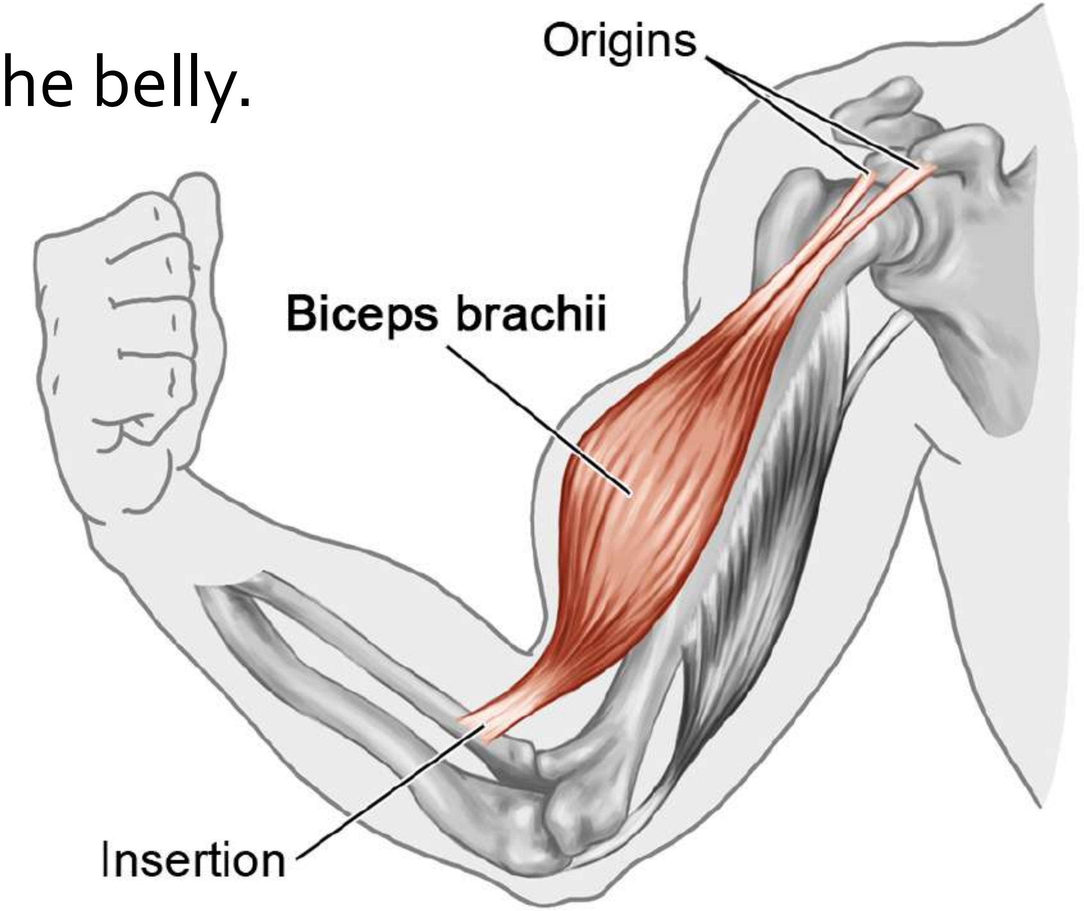
Modulation of Smooth Muscle Activity by Neurotransmitters, Hormones, and Local Factors

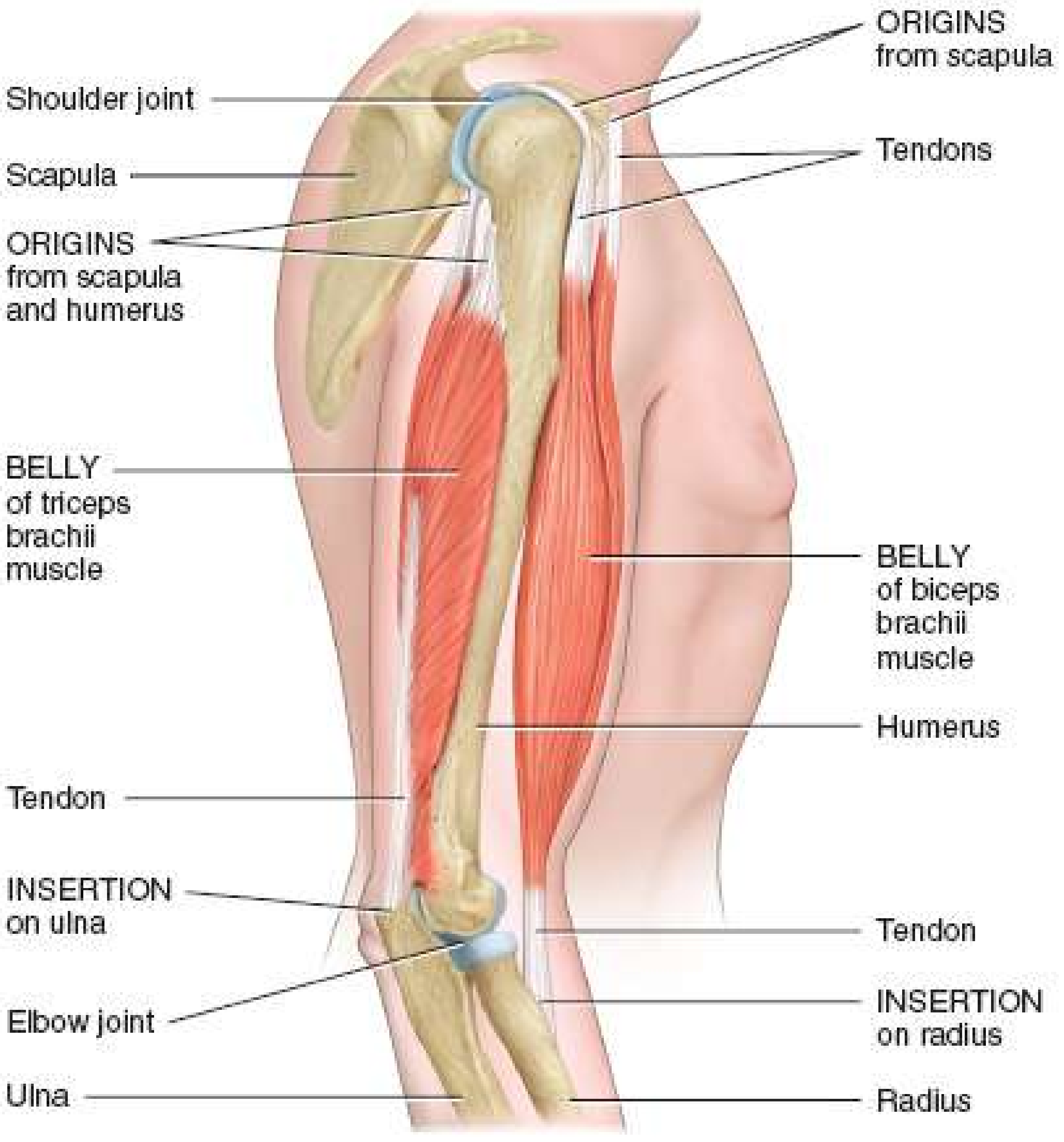
Agonist	Response	Receptor
Norepinephrine and epinephrine from sympathetic stimulation	Contraction* (predominant) Relaxation†	α_1-AR β_2-AR
Acetylcholine from parasympathetic stimulation	Contraction‡ (direct) Relaxation‡ (indirect)	Muscarinic receptor on SMC Muscarinic receptor on EC
Angiotensin II	Contraction§	AT-II receptor
Vasopressin	Contraction§	Vasopressin receptor
Endothelin	Contraction§	Endothelin receptor
Adenosine	Relaxation[Verbar]	Adenosine receptor

How Movement is Produced

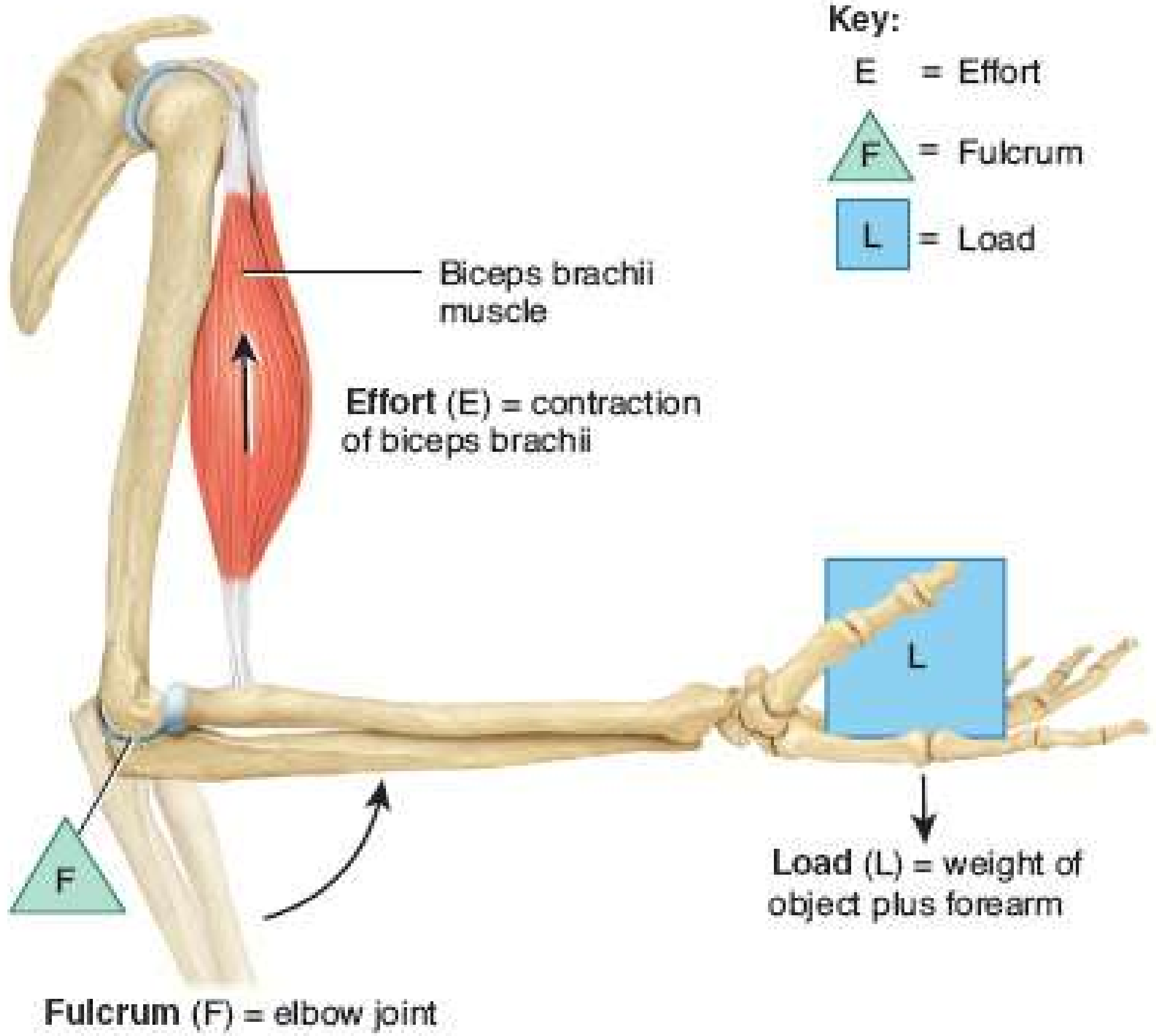
A. Origin and insertion

1. Skeletal muscles pull on bones through tendons. Muscles are attached at both ends to bone. The tendon attached to the stationary bone is called the origin. The other tendon, attached to the moving bone, is called the insertion.
2. The middle part of the muscle is called the belly.





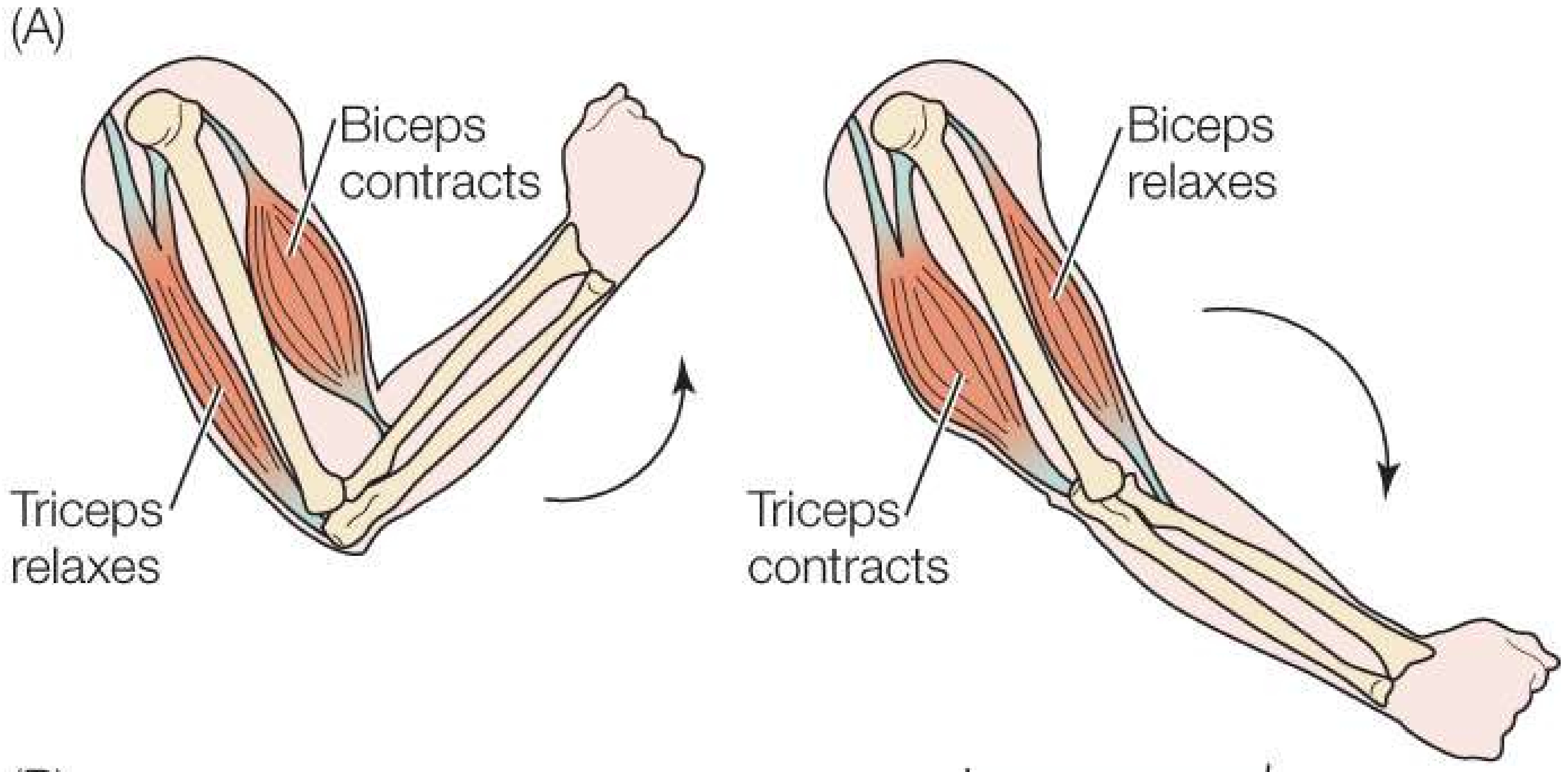
(a) Origin and insertion of a skeletal muscle

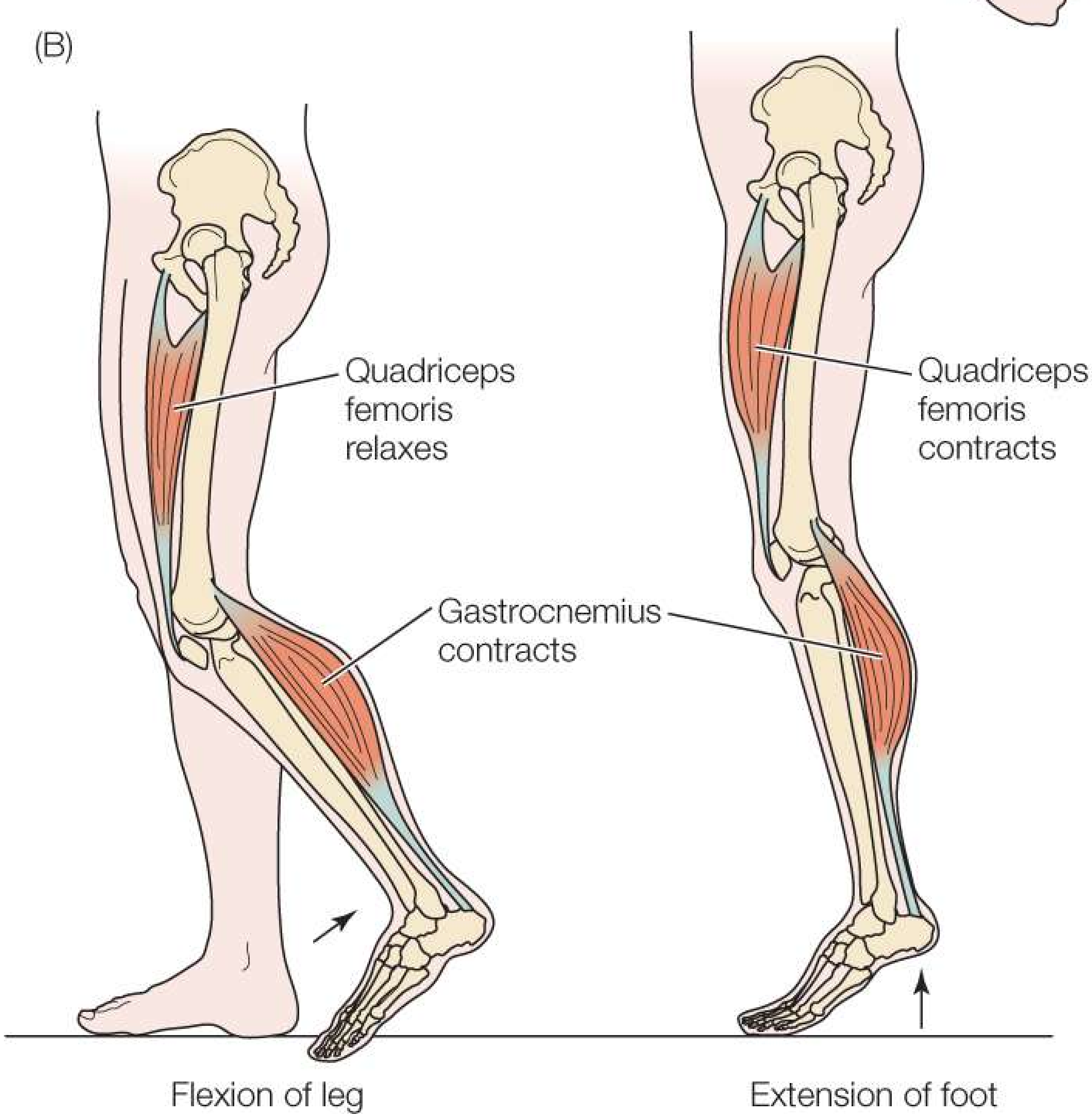


(b) Movement of the forearm lifting a weight

B. Actions

1. Antagonistic – muscles are paired in an antagonistic relationship. EX. Biceps pull the forearm up and triceps pull it back.

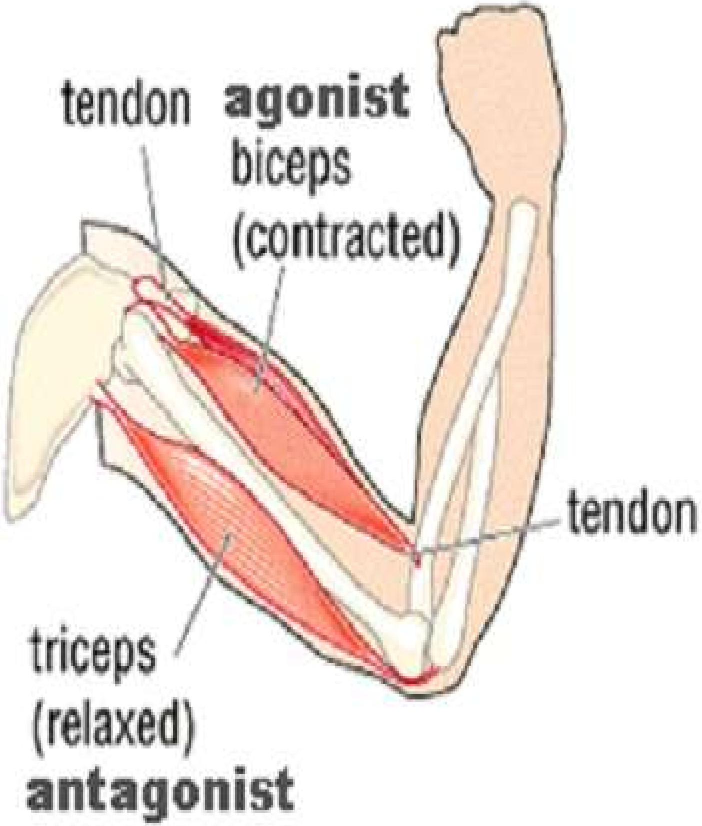


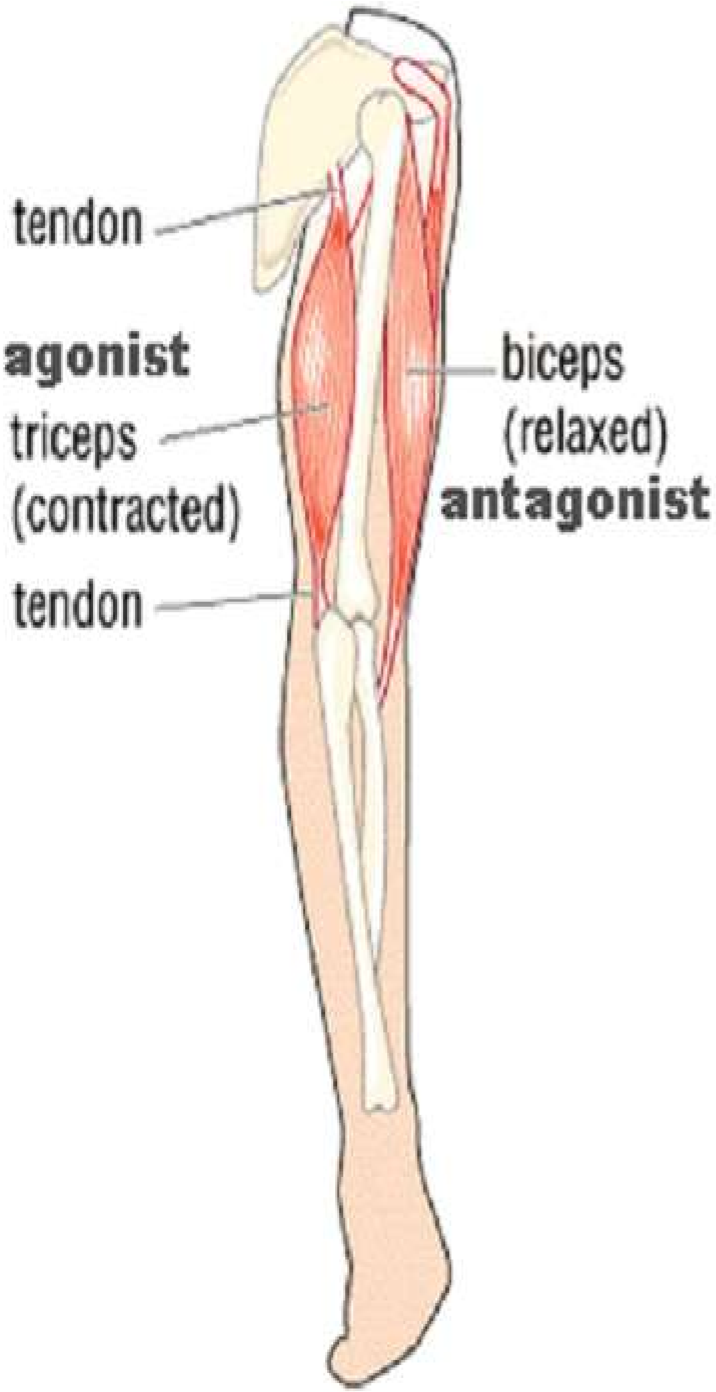

(B)
Quadriceps femoris relaxes
Gastrocnemius contracts
Quadriceps femoris contracts
Flexion of leg
Extension of foot

2. Types

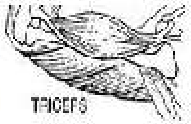
a. Agonist – the primary muscle causing the action – bicep flexing the elbow

b. Antagonist – relaxed during the motion of the agonist, but contracts to return the moved part to its original position – tricep extending out the elbow.





Antagonistic Muscle Groups List

Biceps — Pairs with — Triceps


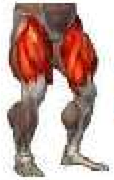
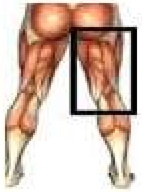

Back — Pairs with — Chest

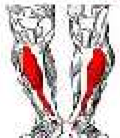
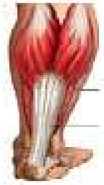


Abs — Pairs with — Lower back



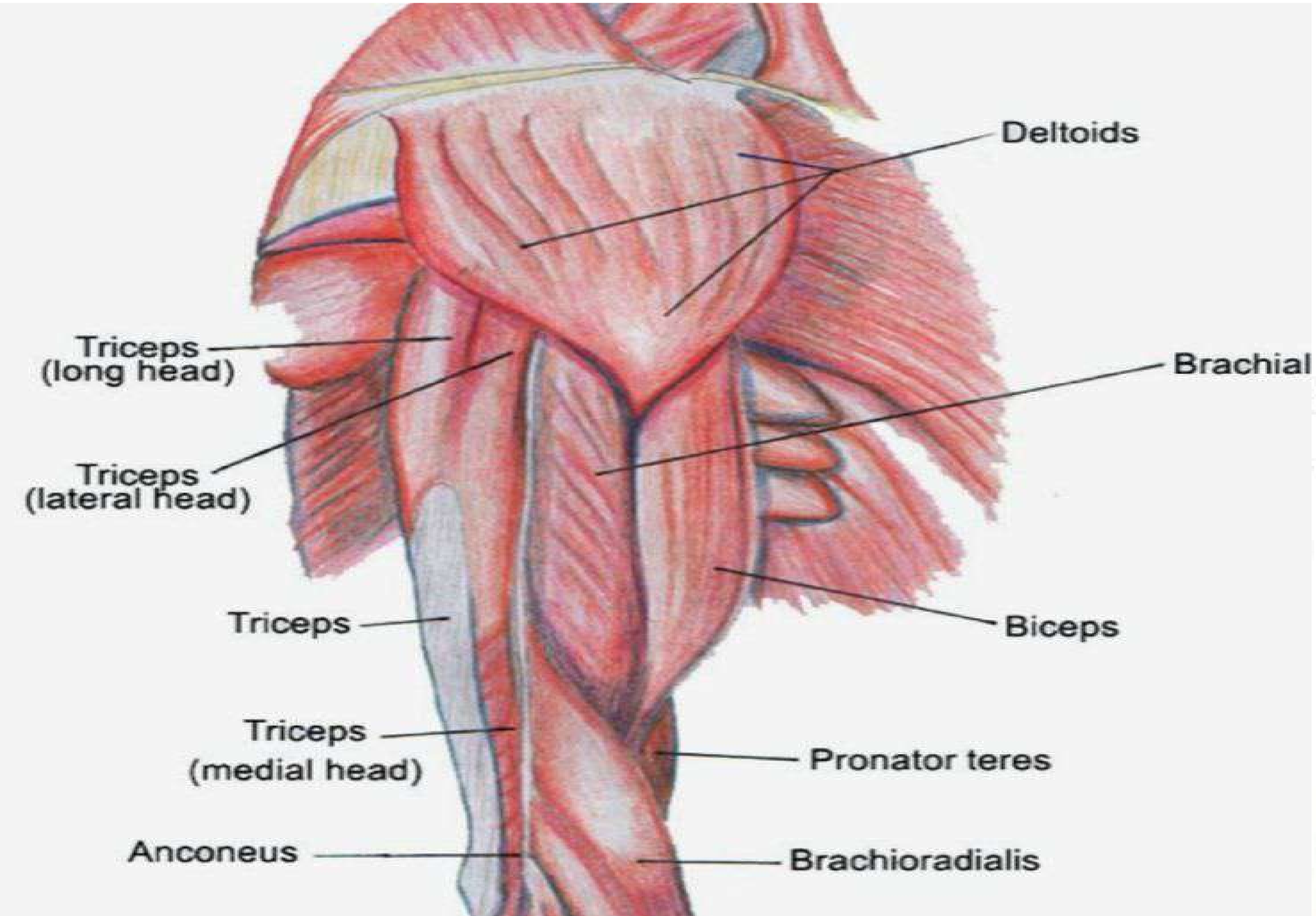
Shoulders — Pairs with — Chest / Back

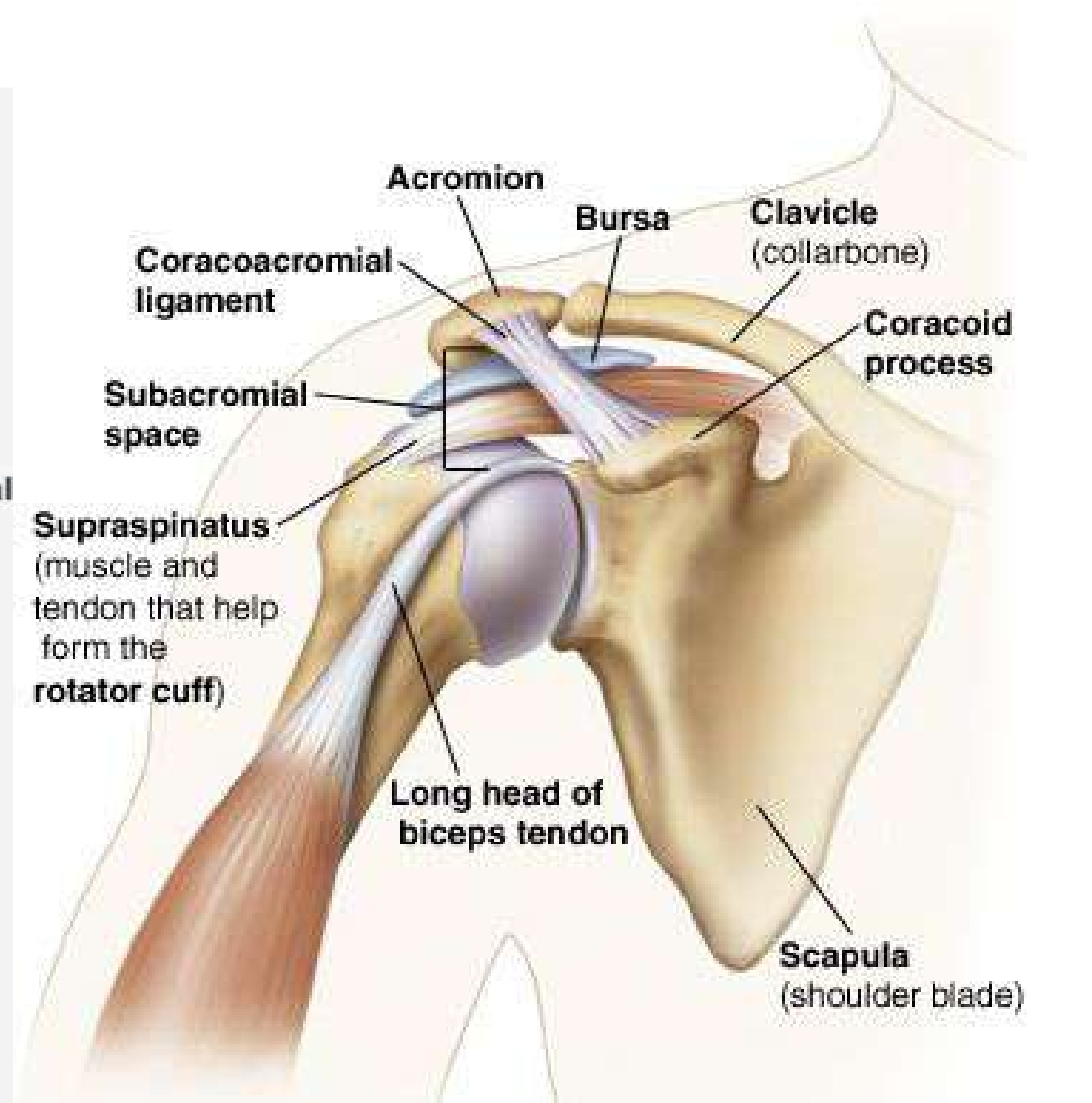

Quadriceps — Pairs with — Hamstring



Tibialis anterior(shin) — Pairs with — Calf muscle


c. Synergist – assists the agonist – the anconeus muscle helps the bicep

d. Fixators – stabilizes the agonist - the rotator cuff muscles stabilize the bicep's motion





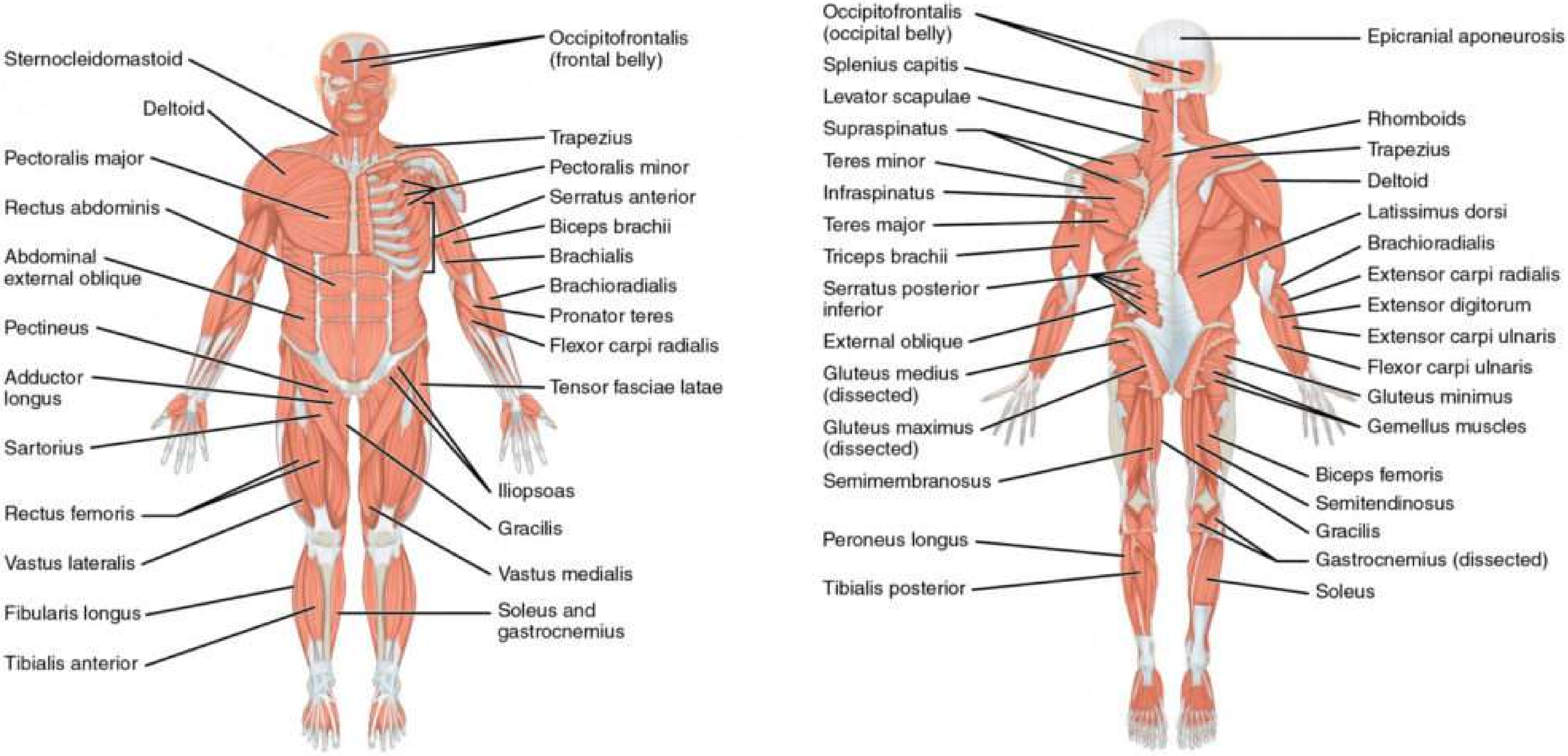
Naming Skeletal Muscles

Muscle can be named using a variety of parameters.

Named according to a number of criteria:

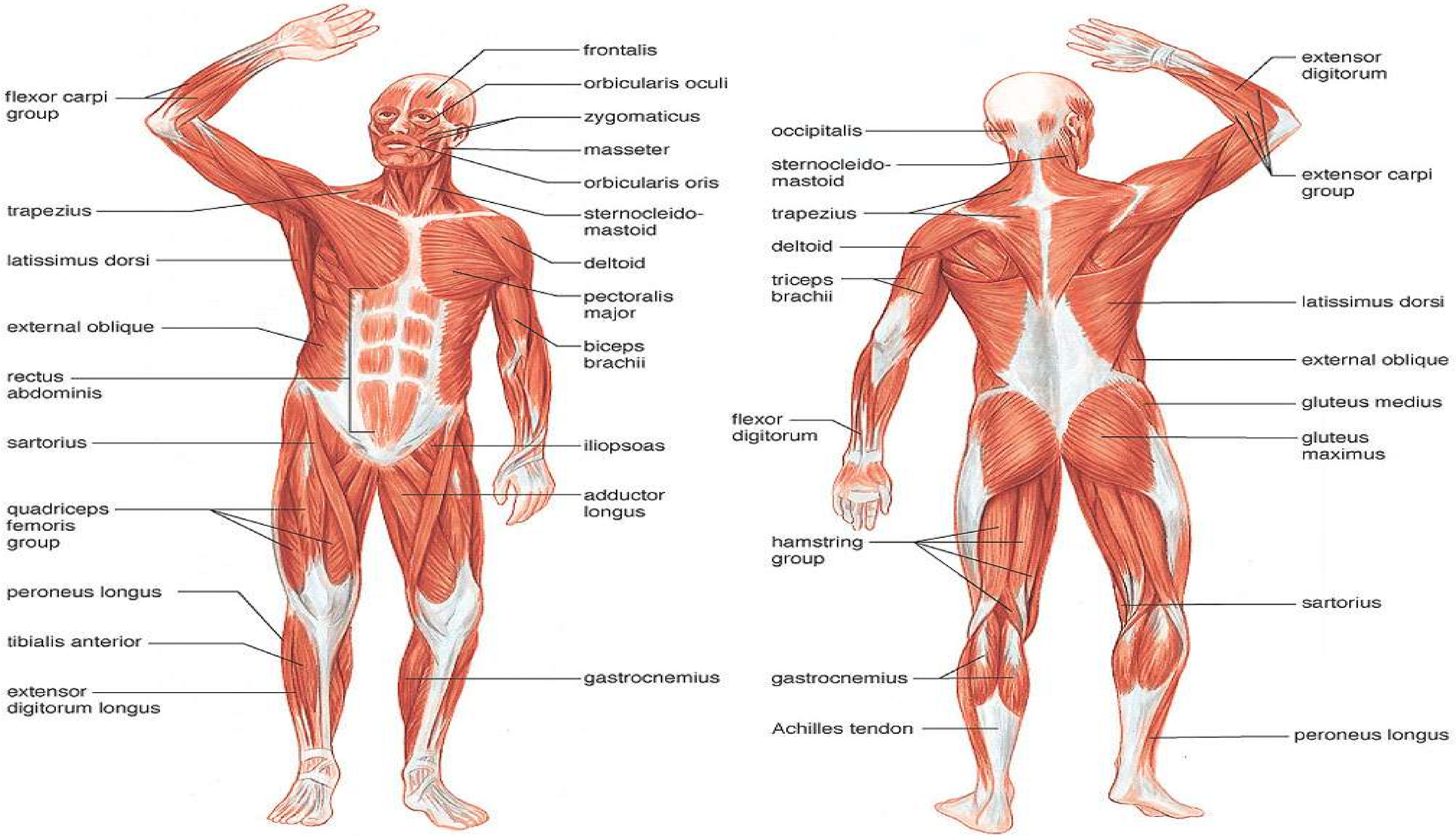
- Direction of muscle fibers relative to longitudinal axis of the muscle
  - **Rectus:** Fibers oriented straight with respect to longitudinal axis
  - **Oblique:** Fibers run at an angle to the longitudinal axis
  - **Orbicularis:** Fibers run in a circular path
- Relative size
  - **Major** for bigger and **minor** for smaller;
  - **Maximus** for biggest, **intermedius** for middle and **minimus** for smallest
  - **Longus** for longest and **brevis** for shortest.
- Location
  - **Pectoralis major** is found in the chest region
  - **Rectus femoris** is found near the femur
- Location of the origin and insertion
  - **Brachioradialis** attaches to the humerus (**origin**) and the radius (**insertion**)
- Number of origins
  - **Biceps** means two heads
  - **Triceps** means three heads
- Shape
  - **Deltoid** means triangular in shape.
  - **Trapezius** is shaped like a trapezium or kite
- Action
  - **Flexor** and **extensor**
  - **Adductor** and **abductor**

Major Muscles of the Body



Anterior view
Right side: superficial; Left side: deep

Posterior view
Right side: superficial; Left side: deep



a. Anterior view

b. Posterior view