Muscle contraction, neural control and muscle dysorder

objectives

- Muscle contraction
- Energy for contraction
- Muscle fatique
- Motor unit
- Muscle control
- Muscle disorder terminology

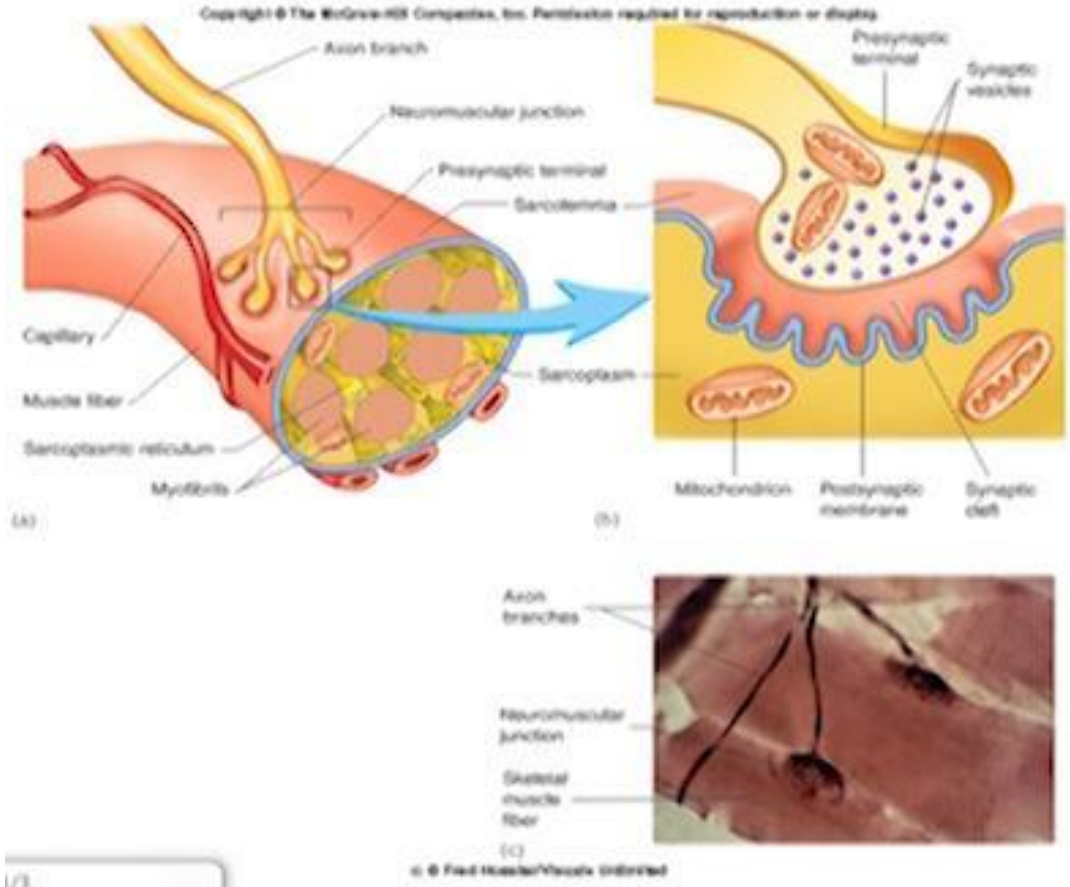
Muscle contraction

Initiation of Muscle Contraction

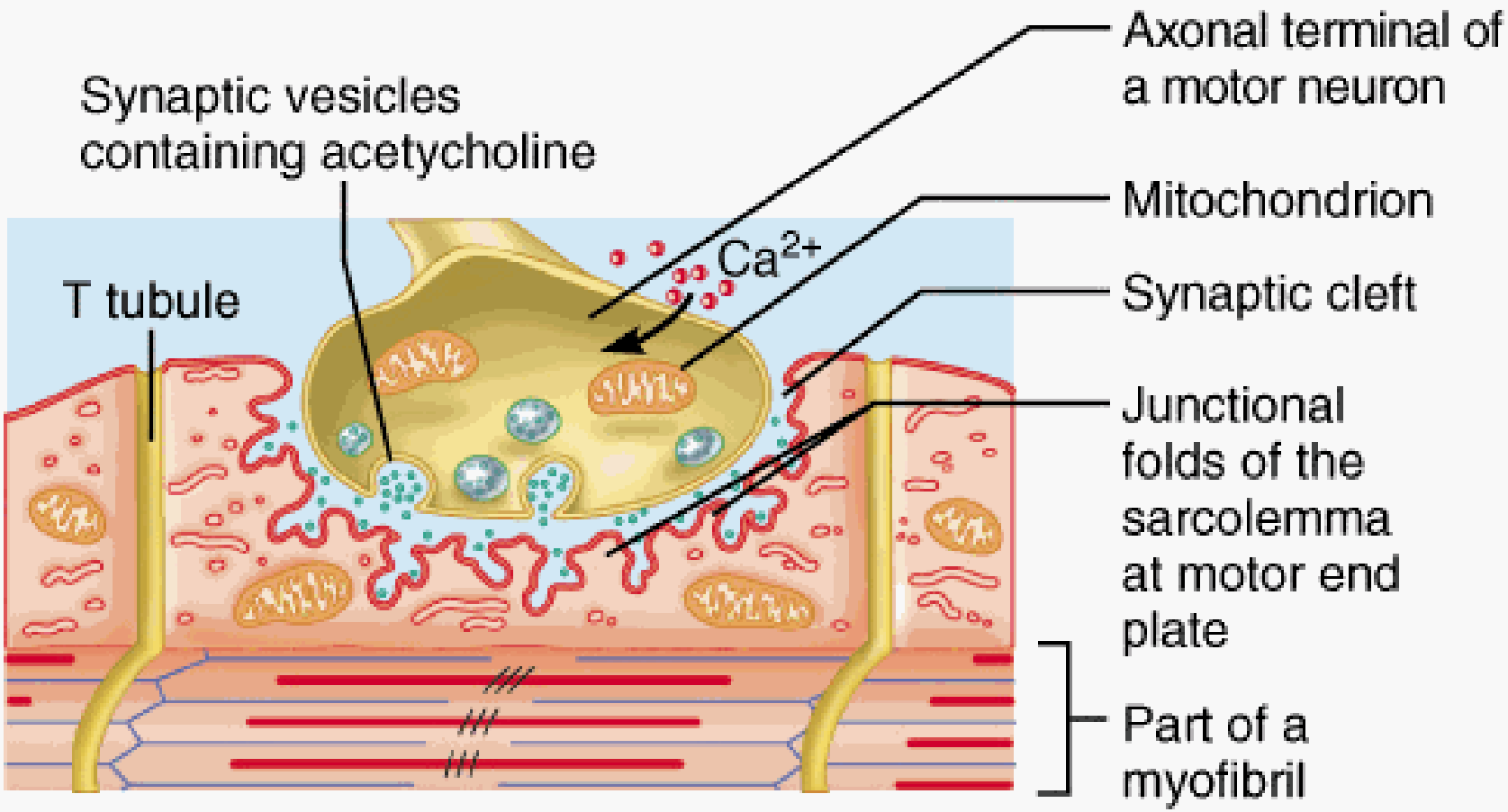
Step 1) Neuromuscular Control

- The axons of the nerve cells of the spinal cord branch and attach to each muscle fiber forming a neuromuscular junction.
- i). An action potential passes down the nerve.
- ii). The nerve releases **Ca++** that results in the release of Acetylcholine (ACh)

Neuromuscular Junction



- Synapse: axon terminal resting in an invagination of the sarcolemma
- **Neuromuscular junction** (NMJ):
  - **Presynaptic terminal**: axon terminal with synaptic vesicles
  - **Synaptic cleft**: space
  - **Postsynaptic membrane** or **motor end-plate**



(b)

Step 2). ACh binds with the sarcolemma

Step 3). Muscle Fiber Action Potential

- **i).** ACh binds with receptors and opens Na+ channels

  Na+ Channels open and Na+ in

  There is a decrease in the resting potential

- **ii**). Na + rushes in and the sarcolemma depolarizes.
- **iii). The regional depolarization spreads rapidly.**

  The positive patch in the membrane changes the adjacent patch of the membrane. Thus depolarization spreads.

- **iv). The K+ channels open and the region repolarizes**

  Immediately after the action potential passes the membrane permeability changes again. Na+ channels close and K+ channels open. K+ rushes out of the cell. Cell repolaraizes

- **Step 4). Ca++ is released from the sarcoplasmic reticulum.**

  i). Ca++ is stored in the sarcoplasmic reticulum.

  ii). Depolarization releases the Ca++.

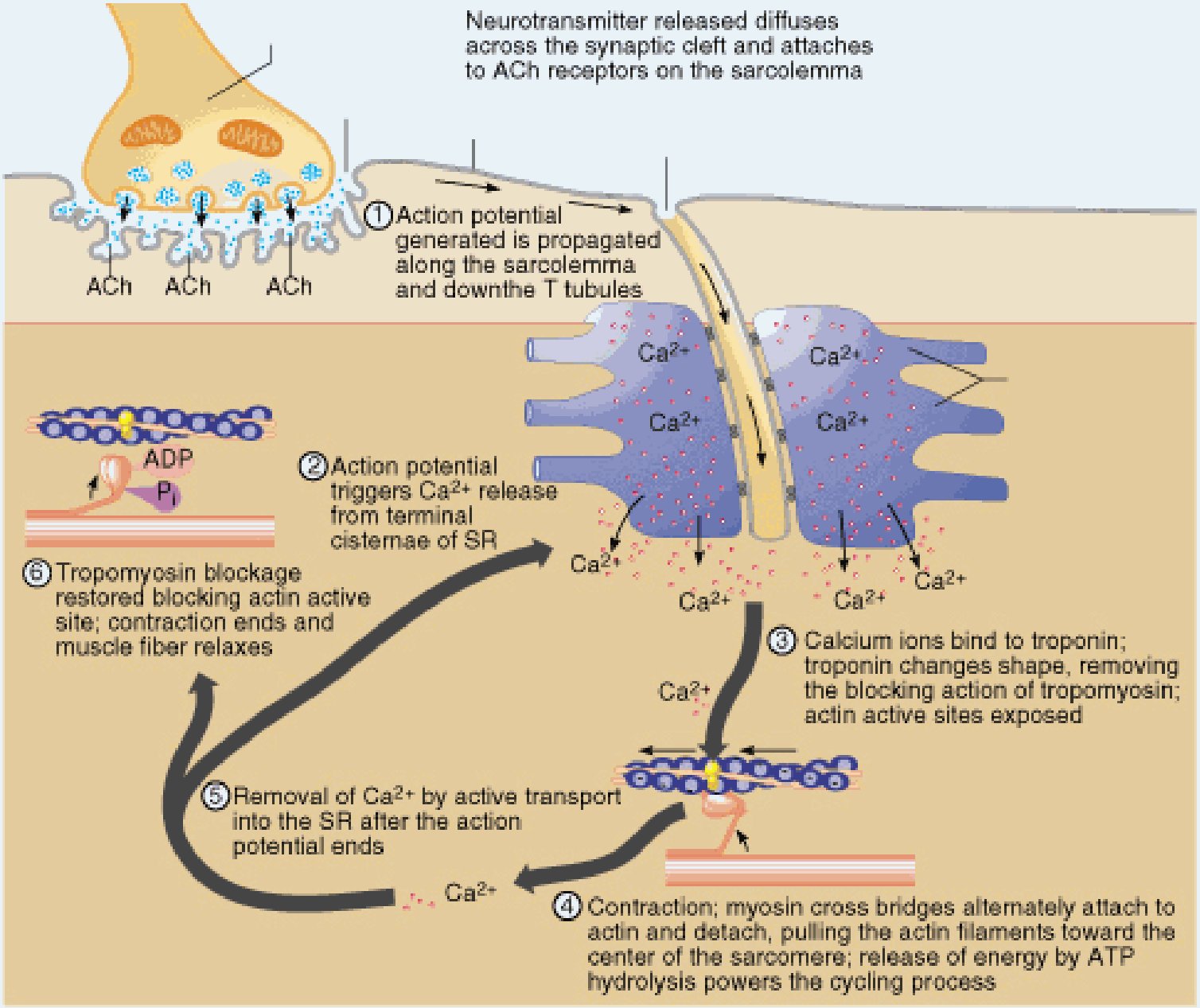
  iii). The Ca++ clears the actin binding sites.

- **Step 5). Sliding Filament Theory of Contraction**

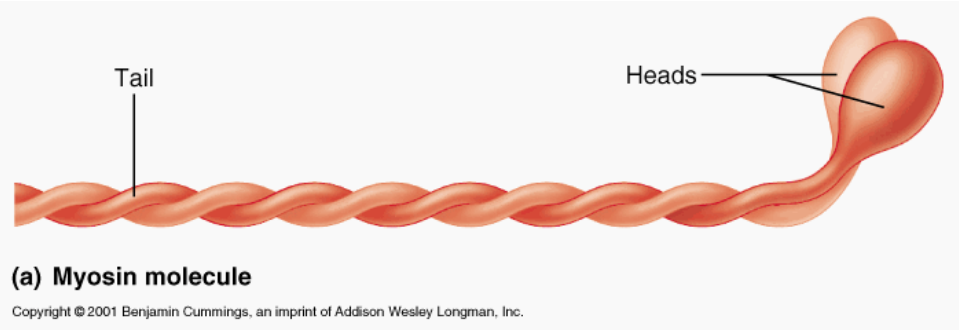
  During muscle contraction the thin actin filaments slide over the thick myosin filament.

  When Calcium is present the blocked active site of the actin clears.

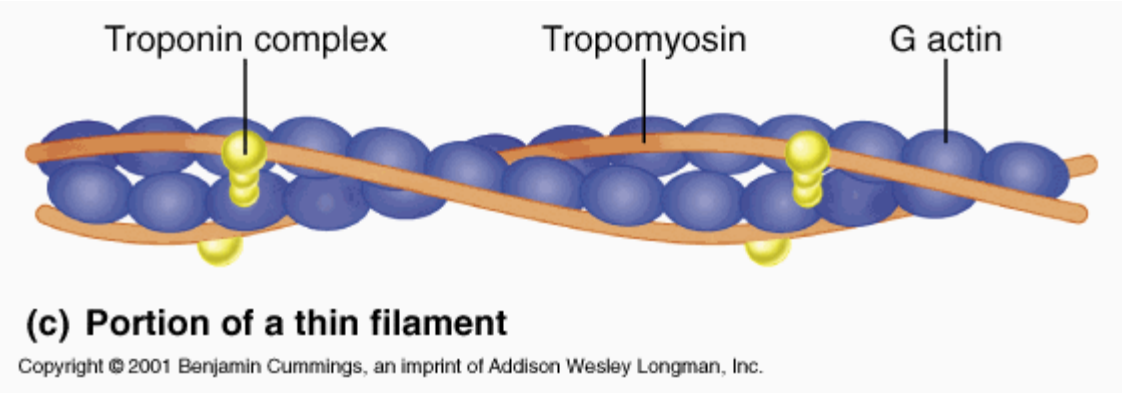
- **Step A**: Myosin head attaches to actin. (**High energy ADP + P configuration)**
- **Step B: Power stroke**: myosin head **pivots pulling the actin filament toward the center.**
- **Step C**: **The cross bridge detaches** when a new ATP binds with the myosin.
- **Step D**: Cocking of the myosin head occurs when ATP à ADP + P. **Another cross bridge can f**orm.



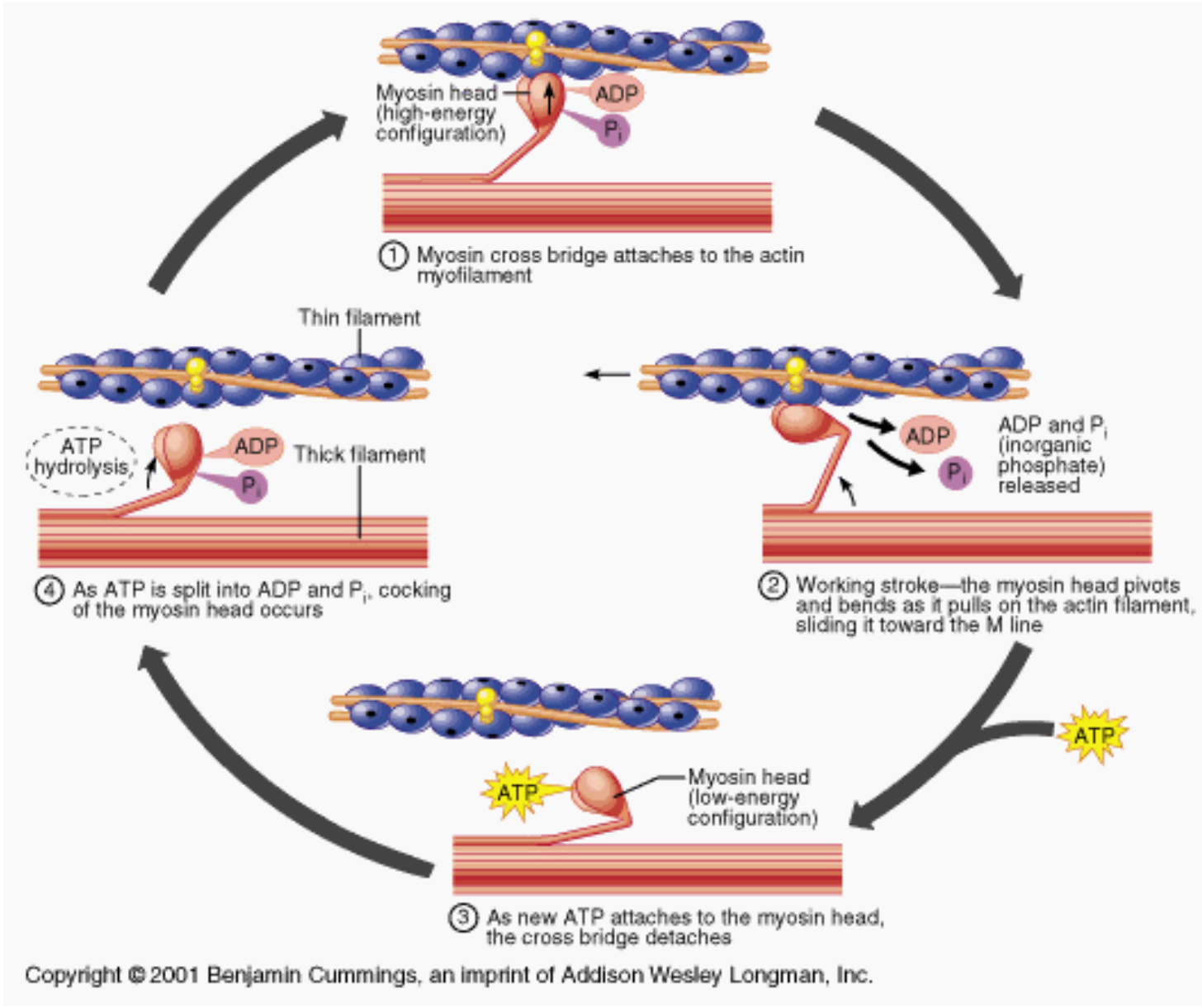
Thick filament (MYOSIN)
Thin Filament (Actin)



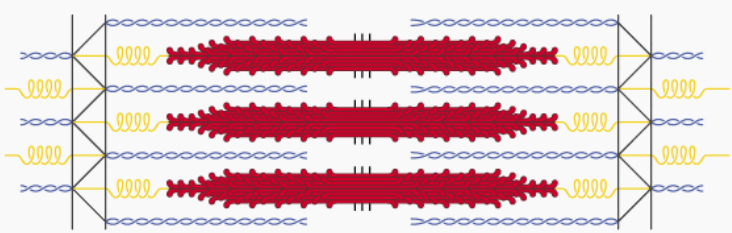
(a) Myosin molecule



(c) Portion of a thin filament



- The end result is a shortening of the sarcomere.
- The distance between the **Z discs** shortens
- The **H zone** disappears
- The **dark A band** increases because the actin & the myosin overlap more
- The **light I band** shortens.
- **Step 6). Ca++ is removed from the cytoplasm**
- **Step 7). Tropomysin blocks the actin site**



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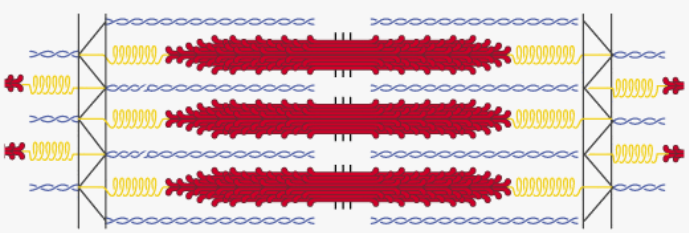

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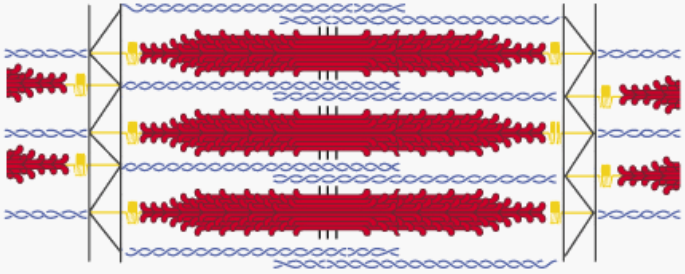

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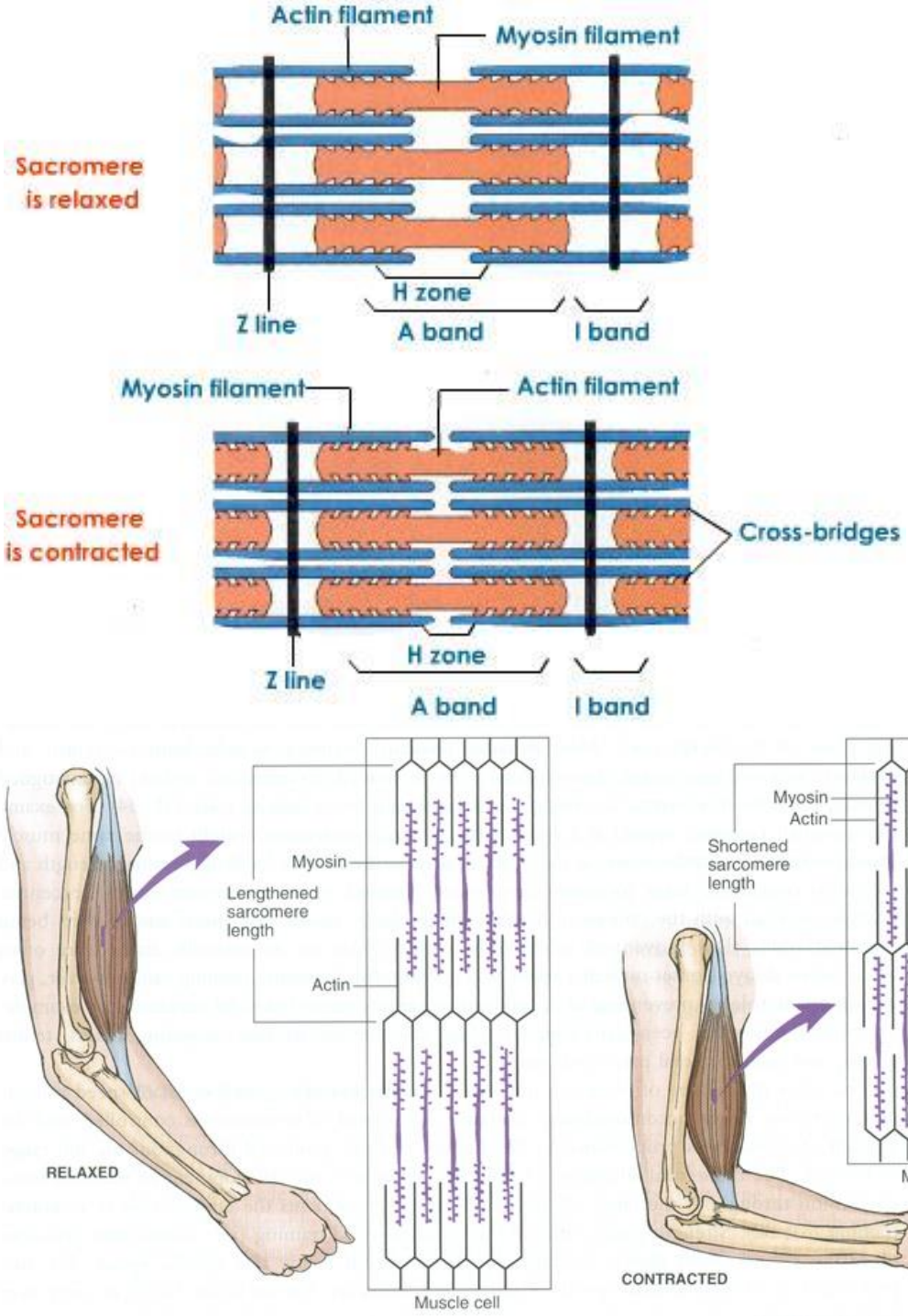
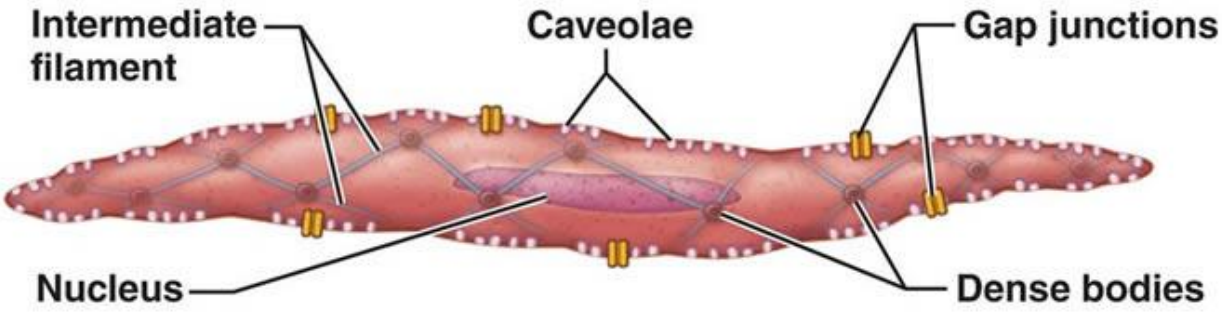

Actin filament
Myosin filament
Sacromere is relaxed
H zone
Z line
A band
I band
Myosin filament
Actin filament
Sacromere is contracted
Cross-bridges
H zone
Z line
A band
I band
Myosin
Lengthened sarcomere length
Actin
RELAXED
Muscle cell
Myosin
Actin
Shortened sarcomere length
Muscle cell
CONTRACTED

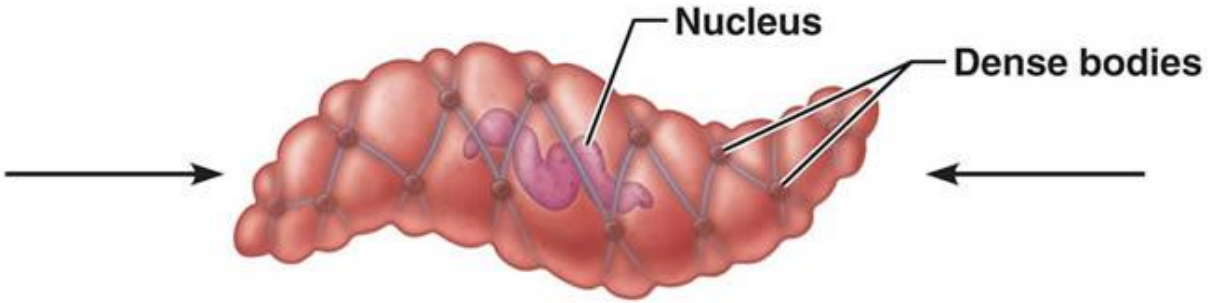
TABLE 9.1 Muscular Contraction and Relaxation

Muscle Fiber Contraction	Muscle Fiber Relaxation
1. The distal end of a motor neuron releases acetylcholine.	1. Acetylcholinesterase decomposes acetylcholine, and the muscle fiber membrane is no longer stimulated.
2. Acetylcholine diffuses across the gap at the neuromuscular junction.	2. Calcium ions are actively transported into the sarcoplasmic reticulum.
3. The sarcolemma is stimulated, and a muscle impulse travels over the surface of the muscle fiber and deep into the fiber through the transverse tubules and reaches the sarcoplasmic reticulum.	3. ATP causes linkages between actin and myosin filaments to break without ATP breakdown.
4. Calcium ions diffuse from the sarcoplasmic reticulum into the sarcoplasm and bind to troponin molecules.	4. Cross-bridges recock.
5. Tropomyosin molecules move and expose specific sites on actin filaments.	5. Troponin and tropomyosin molecules inhibit the interaction between myosin and actin filaments.
6. Actin and myosin filaments form linkages.	6. Muscle fiber remains relaxed, yet ready until stimulated again.
7. Actin filaments are pulled inward by myosin cross-bridges.	
8. Muscle fiber shortens as a contraction occurs.	

Smooth muscle contraction

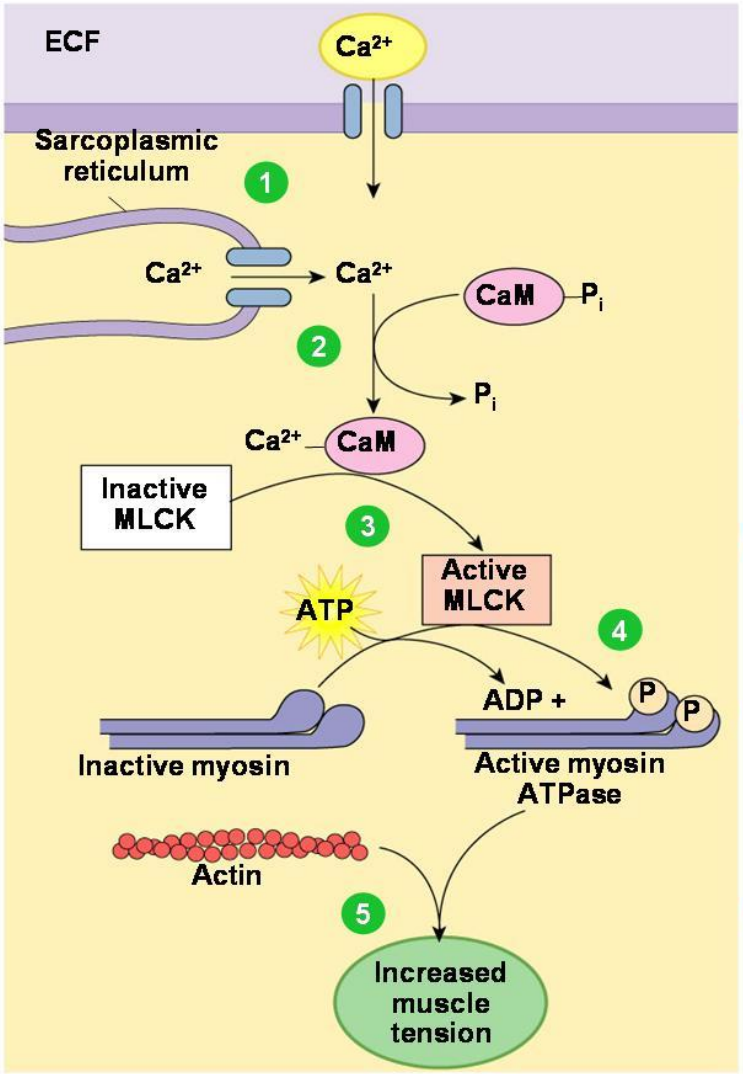


(a) Relaxed smooth muscle fiber (note that gap junctions connect adjacent fibers)



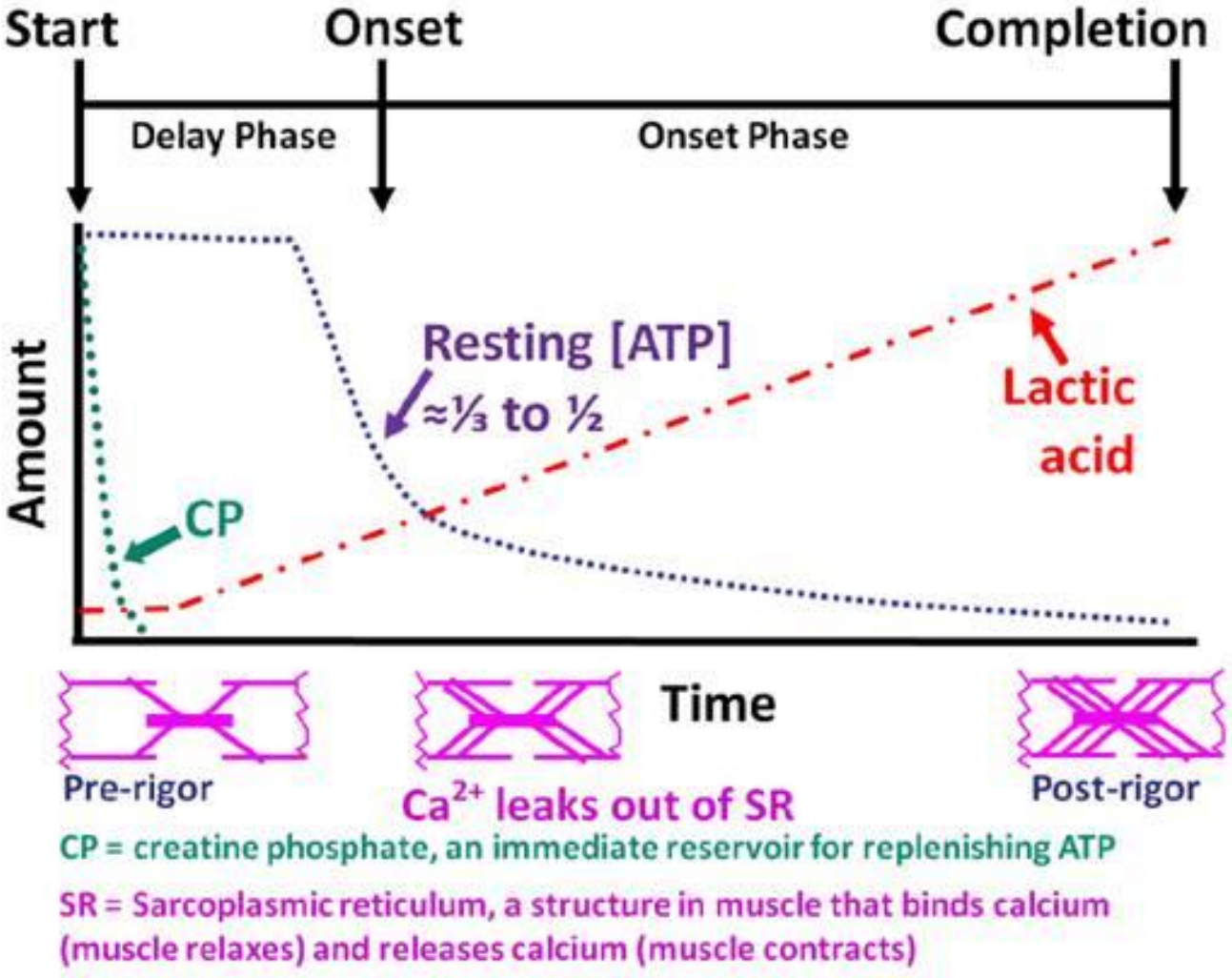
(b) Contracted smooth muscle fiber

Smooth muscle contraction



1. Intracellular Ca^{2+} concentrations increase when Ca^{2+} enters cell and is released from sarcoplasmic reticulum.
2. Ca^{2+} binds to calmodulin (CaM).
3. Ca^{2+}–calmodulin activates myosin light chain kinase (MLCK).
4. MLCK phosphorylates light chains in myosin heads and increases myosin ATPase activity.
5. Active myosin crossbridges slide along actin and create muscle tension.

Rigor mortis



CP = creatine phosphate, an immediate reservoir for replenishing ATP

SR = Sarcoplasmic reticulum, a structure in muscle that binds calcium (muscle relaxes) and releases calcium (muscle contracts)

2. Rigor Mortis

Time	Event	Appearance
2-6 hours	*Rigor begins*	*eyelids, Jaws stiffen*
After 2 hours		*then center of body stiffens*
12 hours	*Complete Rigor*	*Entire body rigid*
15-36	Slow loss of rigor, small muscles first	Lost in head and neck, last is bigger leg muscles
36-48	Rigor disappears, muscles become relaxed	

Energy for muscle contraction

Creatine Phosphate

- Immediate
- Phosphagen system

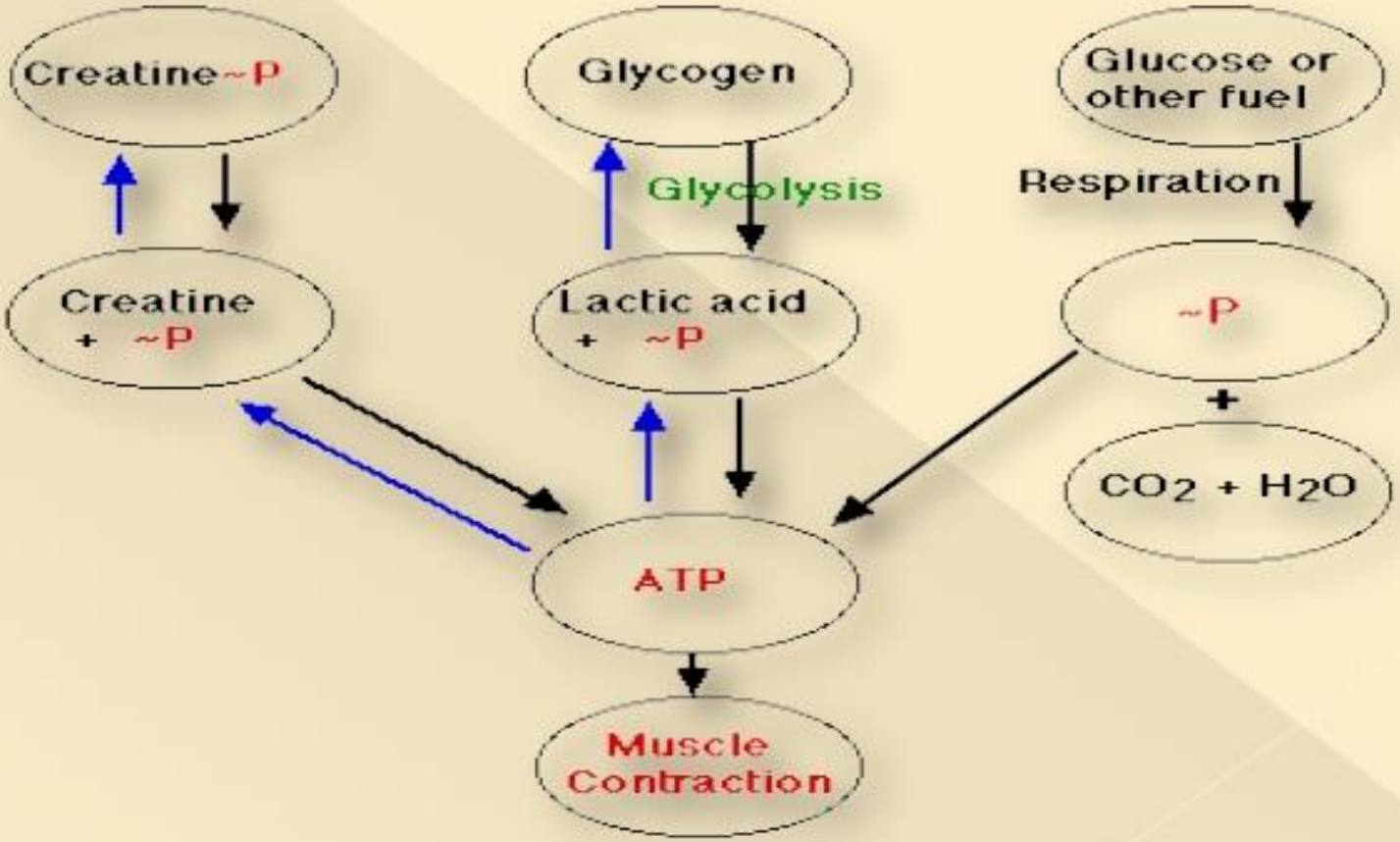
Anaerobic glycolysis

- Short term
- Lactic acid system

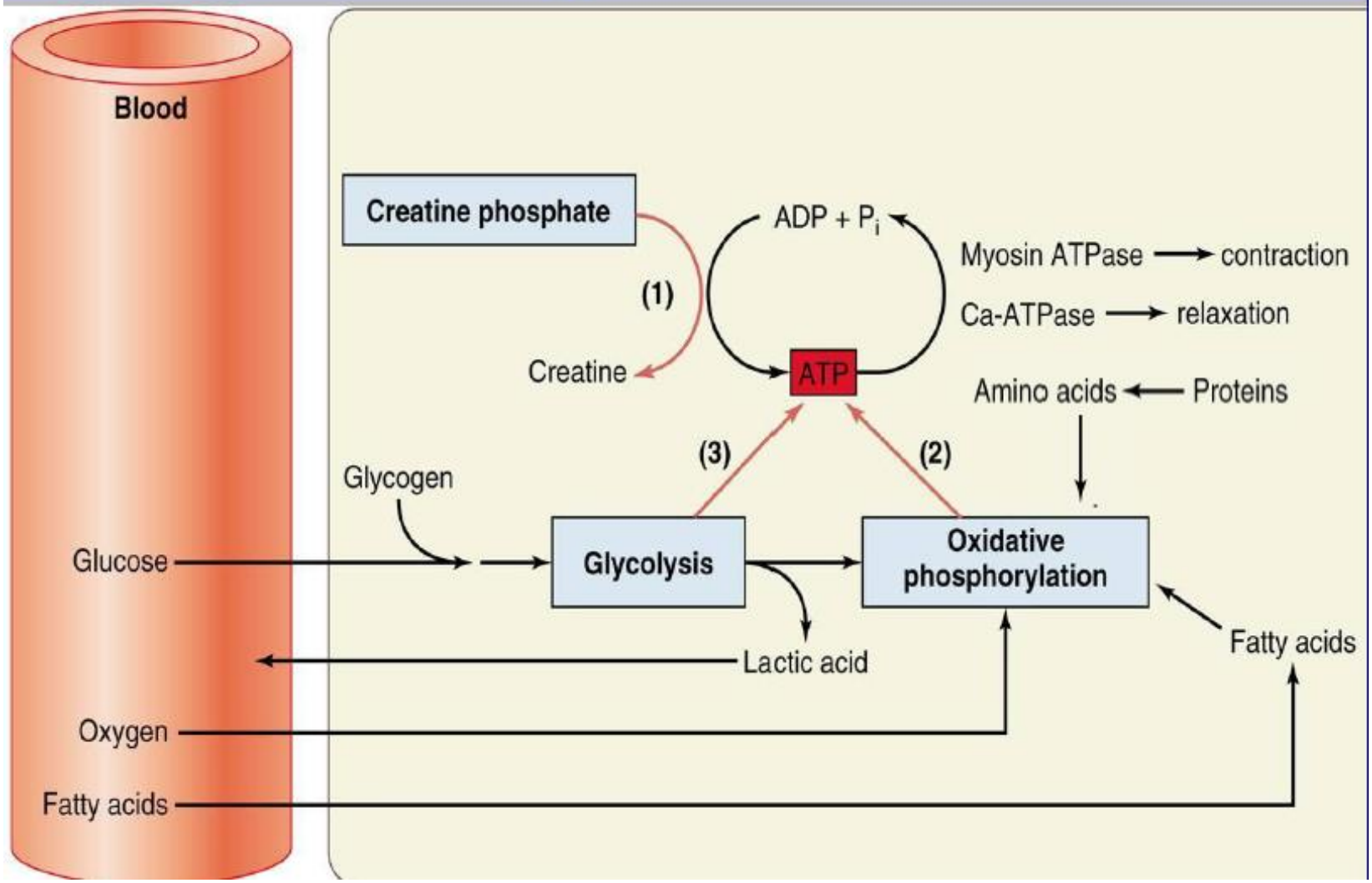
Aerobic glycolysis

- Long term
- Glucose, fatty acids, Amino acids

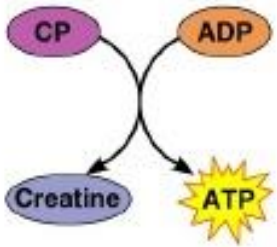
Energy sources of muscle

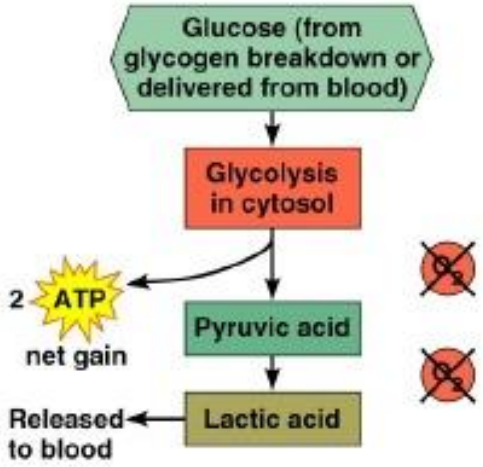


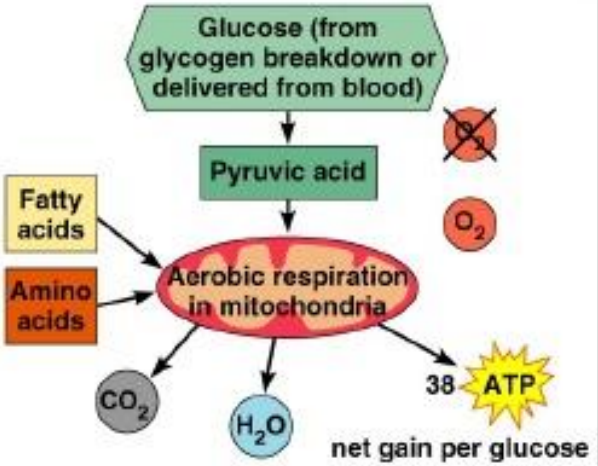
Sources of energy for muscle contraction



Muscle Metabolism: Energy for Contraction







(a) Direct phosphorylation [coupled reaction of creatine phosphate (CP) and ADP]	(b) Anaerobic mechanism (glycolysis and lactic acid formation)	(c) Aerobic mechanism (aerobic cellular respiration)
Energy source: CP	Energy source: glucose	Energy source: glucose; pyruvic acid; free fatty acids from adipose tissue; amino acids from protein catabolism
Oxygen use: None Products: 1 ATP per CP, creatine Duration of energy provision: 15 s.	Oxygen use: None Products: 2 ATP per glucose, lactic acid Duration of energy provision: 30–60 s.	Oxygen use: Required Products: 38 ATP per glucose, CO_2, H_2O Duration of energy provision: Hours

Figure 9.20

Muscle Fatigue-the decline in ability of a muscle to generate force.

- can be a result of vigorous exercise which can cause the build up of lactic acid in the muscles.
- Lactic acid build up can also cause cramps and sore muscles.

HOW DOES IT WORK?

*anaerobic muscle contraction, lactic acid build up, Oxygen debt

Energy Sources

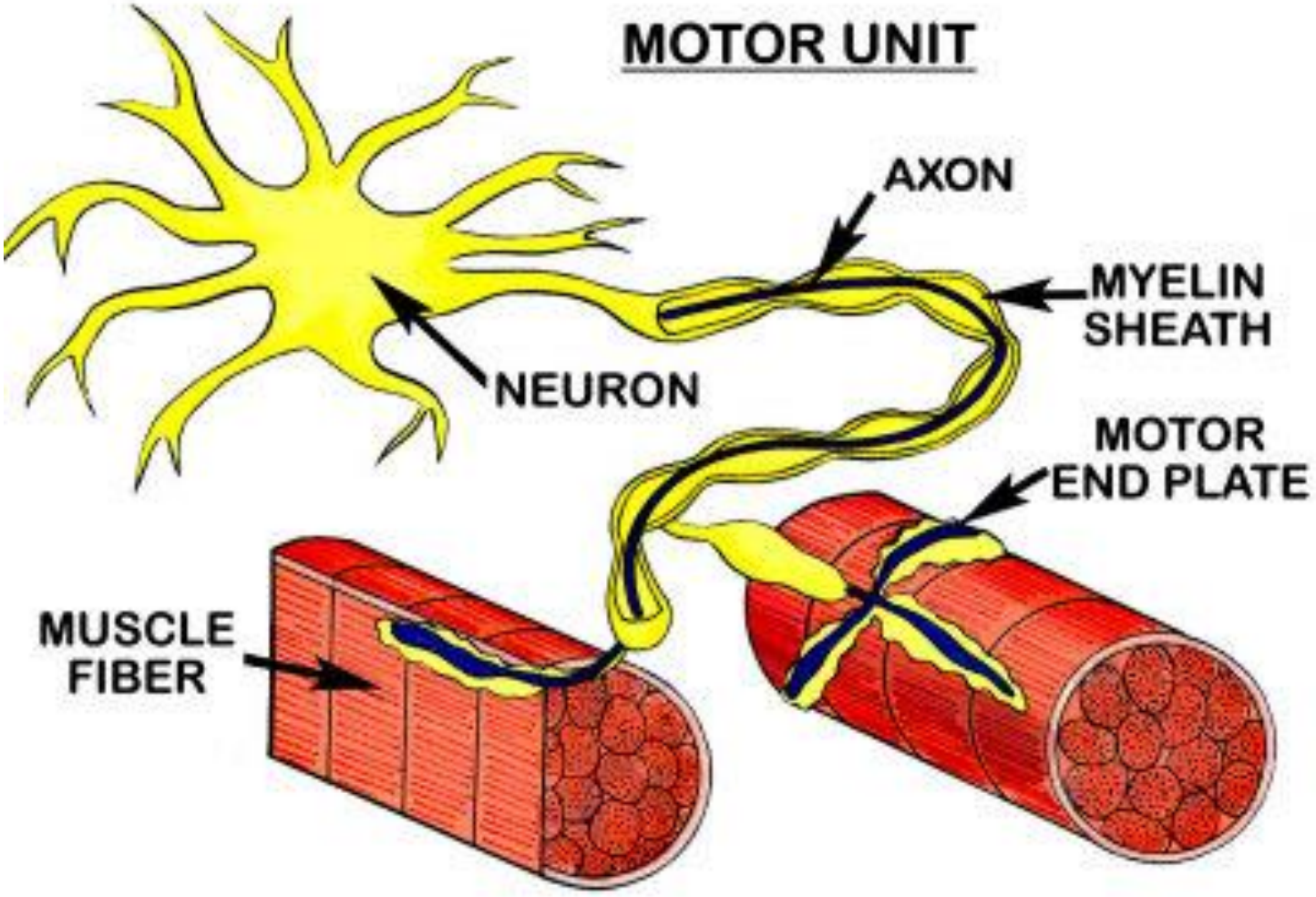
- Muscle Fatigue
  - Muscle loses ability to contract
  - Lactic acid accumulates
  - Cramp: muscle contracts spasmodically, but does not relax completely

During process of ATP release creating energy/heat: lactic acid (byproduct of cellular metabolism) builds up

Increased lactic acid levels in muscles cause muscle fatigue

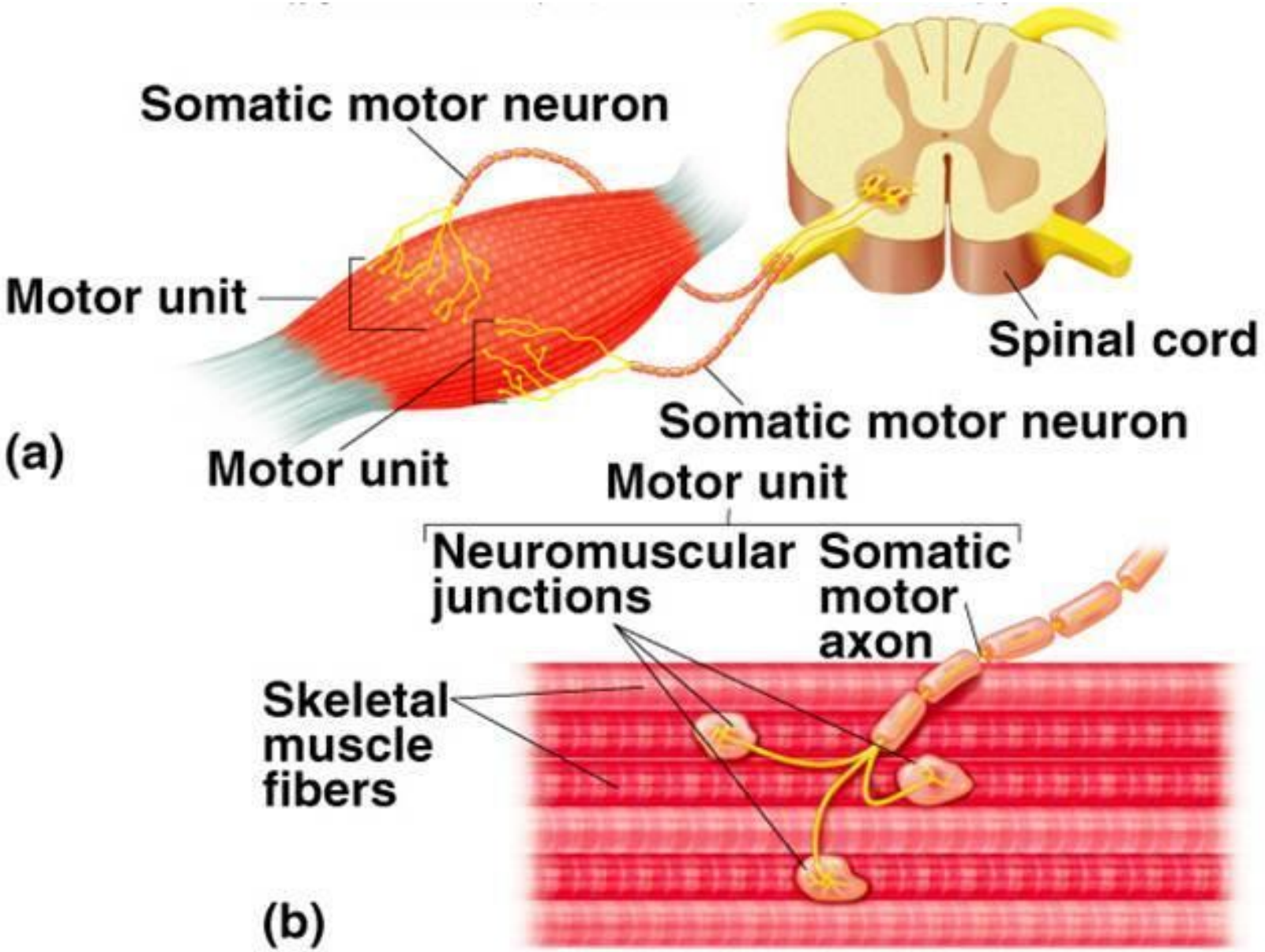
WHY? Vigorous exercise – blood can't transport enough oxygen to complete oxidation of glucose in muscles – muscles contract anaerobically

So why does resting help a cramp?

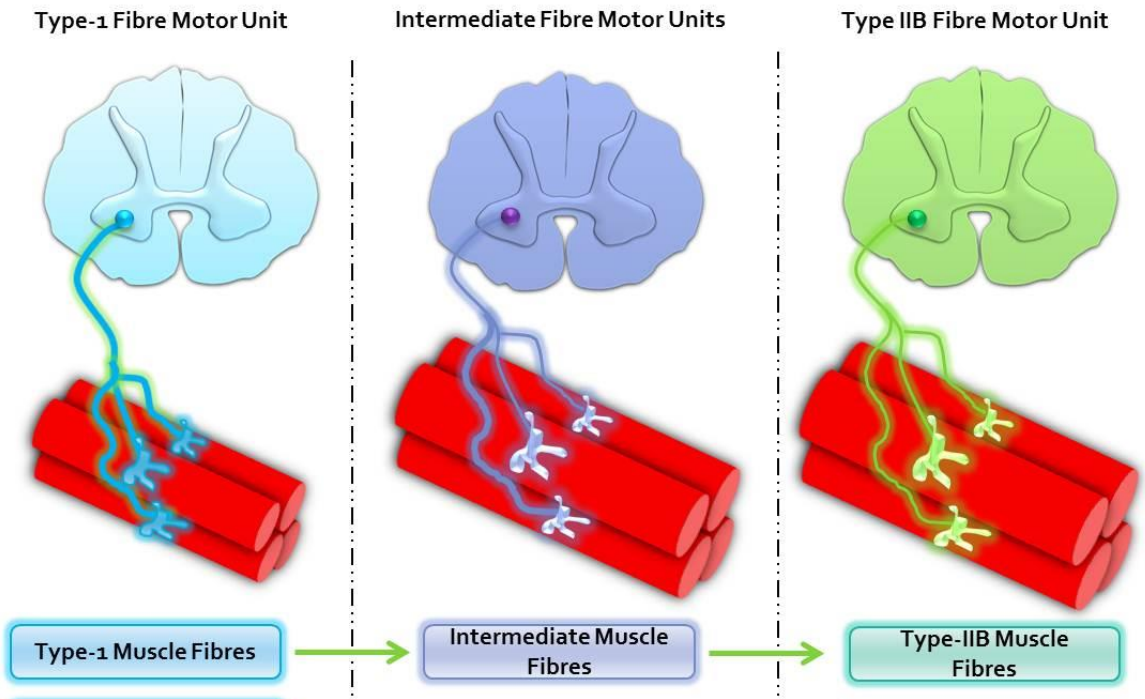

MOTOR UNIT
AXON
MYELIN SHEATH
NEURON
MOTOR END PLATE
MUSCLE FIBER

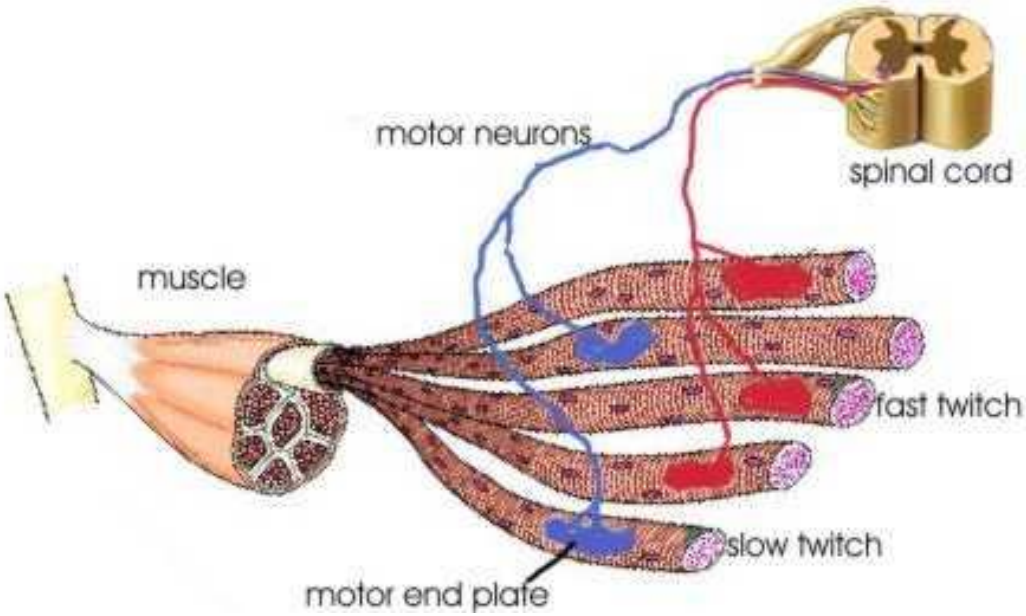
A **motor unit**

- is made up of **a motor neuron** and **the skeletal muscle fibers** innervated by that **motor neuron's axonal terminals**
- Groups of motor units often work together to coordinate the contractions of a single muscle, all of the motor units within a muscle are considered a motor pool
- All muscle fibers in a motor unit are of the same fiber type. When a motor unit is activated, all of its fibers contract.
- The number of muscle fibers within each unit can vary within a particular muscle and even more from muscle to muscle; the muscles that act on the largest body masses have motor units that contain more muscle fibers, whereas smaller muscles contain fewer muscle fibers in each motor unit
- For instance, thigh muscles can have a thousand fibers in each unit, while extraocular muscles might have ten. Muscles which possess more motor units (and thus have greater individual motor neuron innervation) are able to control force output more finely.

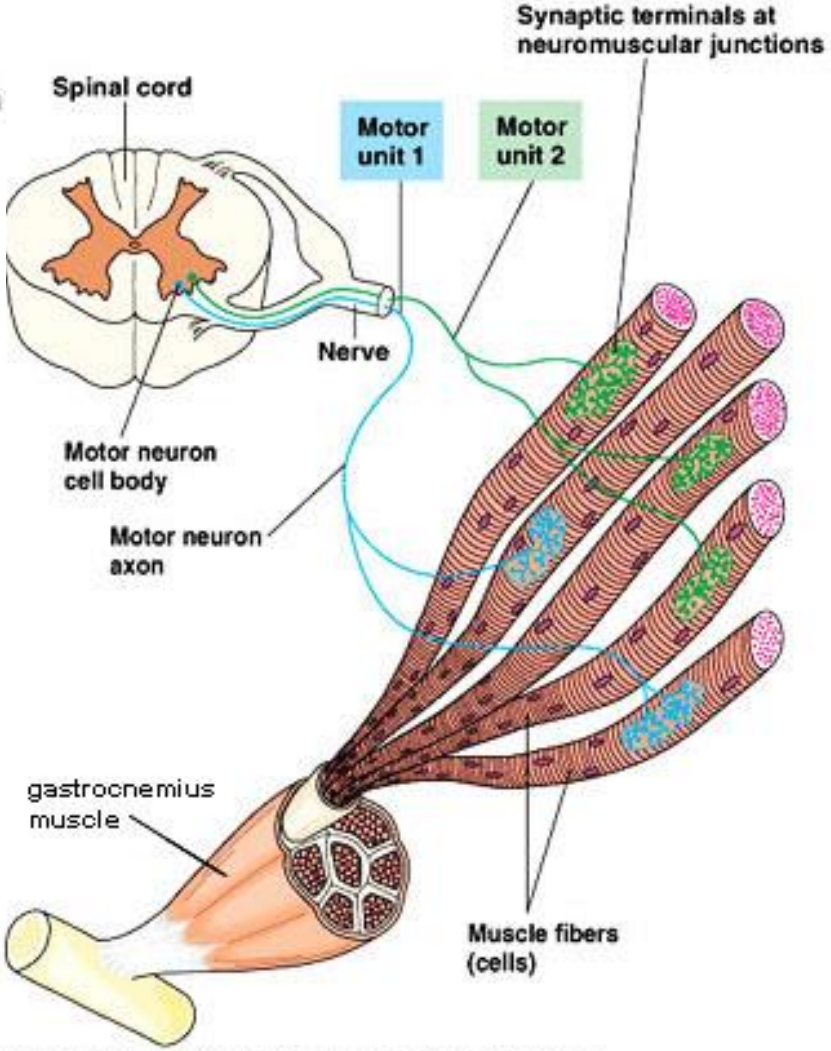

Somatic motor neuron
Motor unit
Spinal cord
Somatic motor neuron
(a)
Motor unit
Motor unit
Neuromuscular junctions
Somatic motor axon
Skeletal muscle fibers
(b)

	Ocular	Skeletal
Fiber diameter	9–17 μm	90–100 μm (gluteus maximus)
Ratio of nerve to muscle fiber	1:1–17	Up to 1:300
Contraction time	Fast	Slow
Acetylcholine sensitivity	High	Low or absent





Slow Twitch	Fast Twitch
Thin motor nerve fibers	Thick motor nerve fibers
Multiply innervated (en grappe)	Singly innervated (en plaque)
Large, poorly delineated muscle fibrils *(Felderstruktur)*	Small, well-delineated muscle fibrils *(Fibrillenstruktur)*
No conduction of action potential	Conduction of action potential
Slow, sustained contraction (tonic)	Fast contraction (phasic)
Predominantly in orbital layer	Predominantly in central (bulbar) layer



Motor neuron

- **Alpha (**α**) motor neurons** (also called **alpha motoneurons**), are large lower motor neurons of the brainstem and spinal cord.
- They innervate **extrafusal muscle fibers** of skeletal muscle and are directly responsible for initiating their contraction.
- While their cell bodie sare found in the **central nervous system (CNS), α motor neurons are also considered part of the somatic nervous system—a** branch **of the peripheral nervous system (PNS**)—because their axons extend into the periphery to innervate skeletal muscles.
- An alpha motor neuron and the muscle fibers it innervates is a motor unit A **motor neuron pool** contains the **cell bodies of all the alpha motor** neurons involved **in contracting a single muscle.**

- **Gamma motor neurons** (**γ motor neurons**), also called **gamma motoneurons**, are a type of lower motor neuron that take part in the process of muscle contraction, and represent about 30% of fibers going to the muscle.
- Like alpha motor neurons, their cell bodies are located in the anterior horn of the spinal cord
- Their axons originate from the bulboreticular facilitatory region of the pons in the brainstem with a diameter of only 5 µm.
- Unlike the alpha motor neurons, gamma motor neurons do not directly adjust the lengthening or shortening of muscles. However, their role is important in **keeping muscle spindles** taut, thereby allowing the firing of alpha neurons to continue discharging, leading to muscle contraction. **These neurons also play a role in adjusting the sensitivity of muscle spindles**
- The presence of myelination in γ motor neurons allows a conduction velocity of 4 to 24 meters per second, significantly faster than with non-myelinated axons but slower than in alpha motor neurons

Muscle Control

- Skeletal muscle can only pull to produce movement; they cannot push. They pull by working in pairs or groups – that is, as a muscle contracts on the front side of the body (anterior), usually the muscles at the back (posterior) with the opposite action relax.
- **Reciprocal Inhibition** – states that when one muscle is contraction, the opposite muscle in the pair is relaxing. It is a balanced process of relaxation and contraction of the agonist and antagonist.

Two Types of Muscles

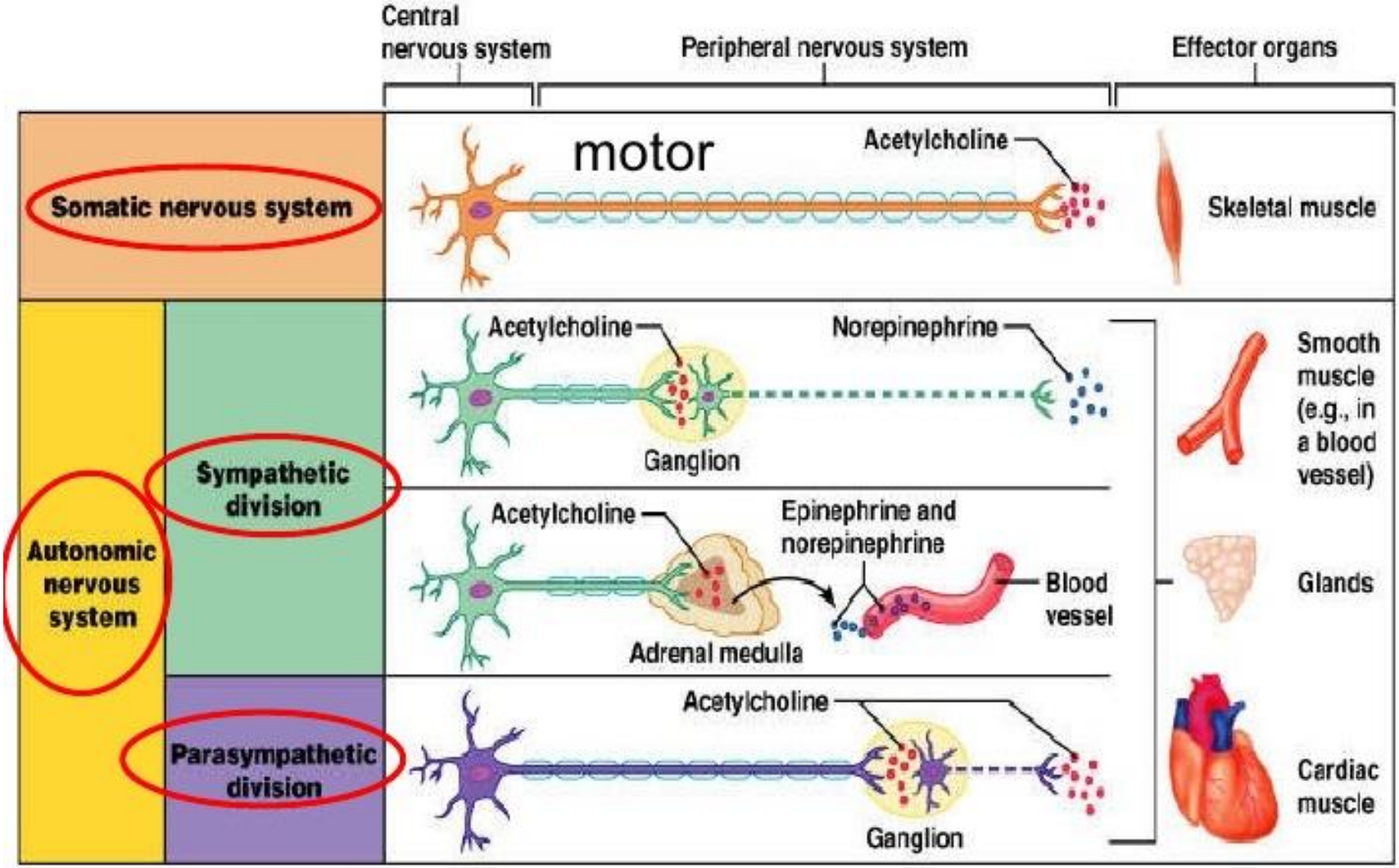
VOLUNTARY

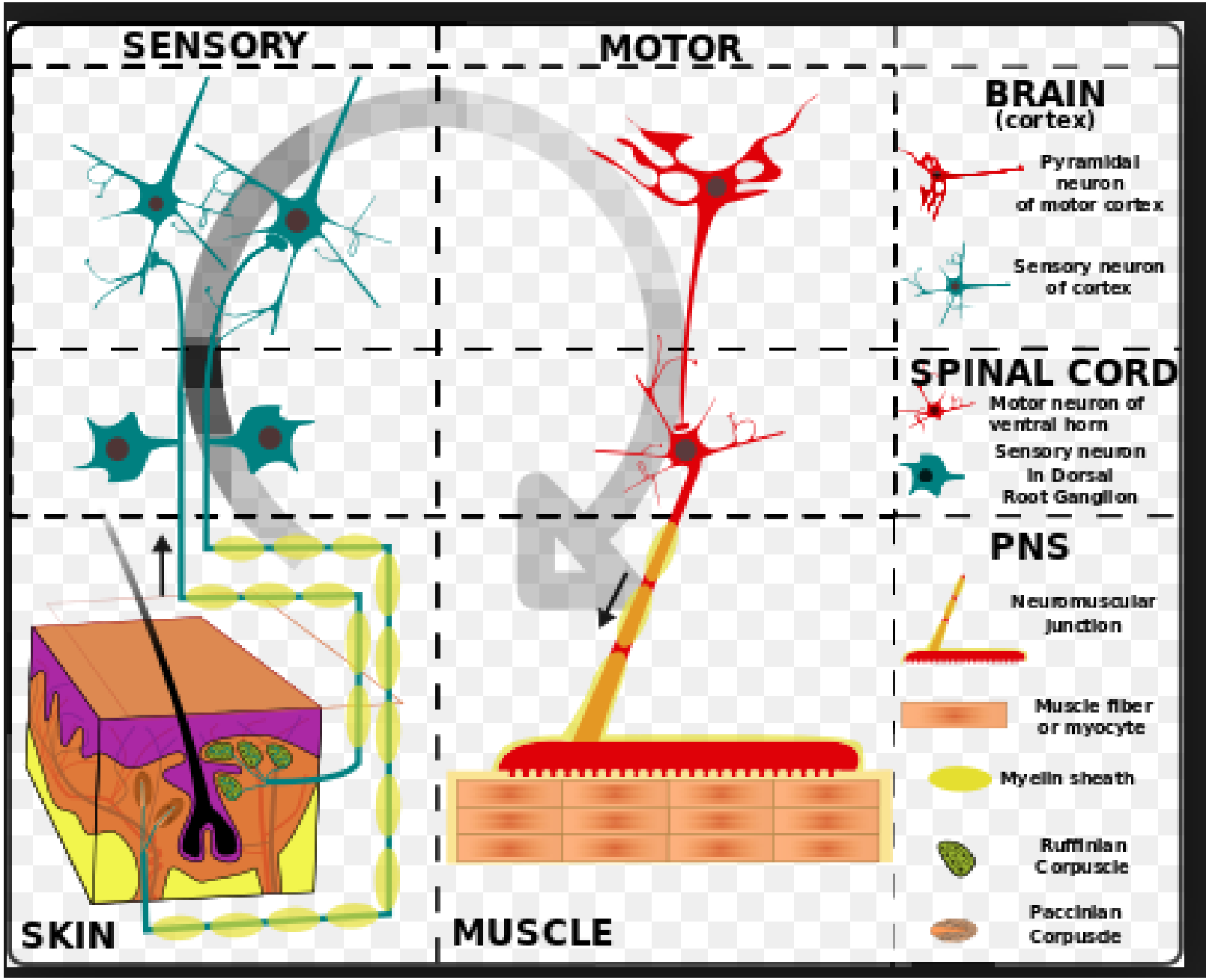
- Muscles you **can** control
  - Most of them work to move your bones
  - The brain sends a message to your muscles to relax or contract depending on the movement you want to do

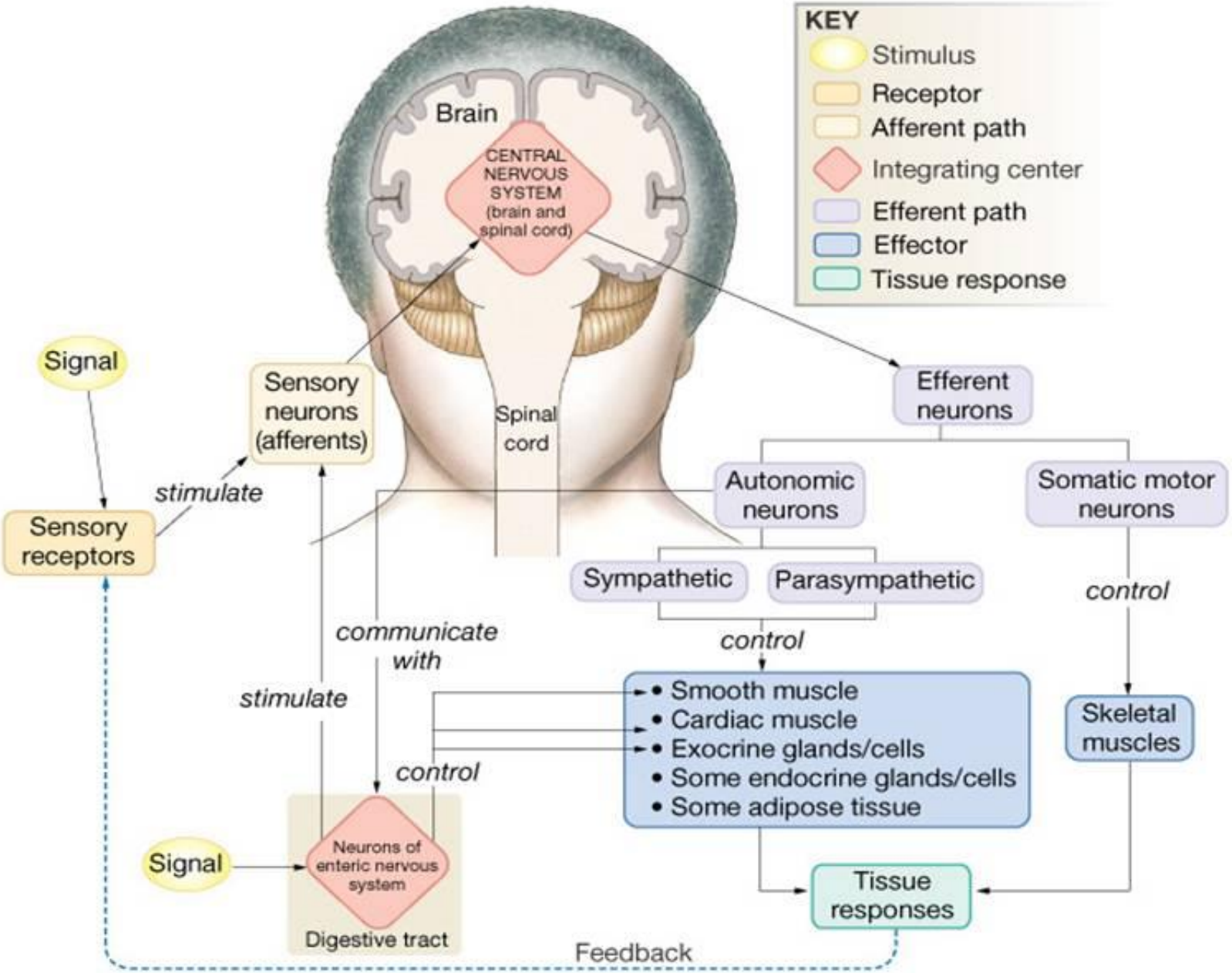
INVOLUNTARY

- Muscles you **can not** control
  - The brain does not need to send these muscles a message
  - They know their job and they automatically do it
    - Examples:
      - Muscles in your heart
      - Muscles in your digestive system
      - Tiny muscles on the bottom of your hairs that makes your hair stand up when you are cold/scared

Somatic # ANS


Central nervous system
Peripheral nervous system
Effector organs
Somatic nervous system
motor
Acetylcholine
Skeletal muscle
Autonomic nervous system
Sympathetic division
Acetylcholine
Norepinephrine
Ganglion
Smooth muscle (e.g., in a blood vessel)
Acetylcholine
Epinephrine and norepinephrine
Blood vessel
Adrenal medulla
Glands
Parasympathetic division
Acetylcholine
Ganglion
Cardiac muscle


SENSORY
MOTOR
BRAIN
(cortex)
Pyramidal neuron of motor cortex
Sensory neuron of cortex
SPINAL CORD
Motor neuron of ventral horn
Sensory neuron in Dorsal Root Ganglion
PNS
Neuromuscular junction
Muscle fiber or myocyte
Myelin sheath
Ruffinian Corpuscle
Paccinian Corpuscle
SKIN
MUSCLE

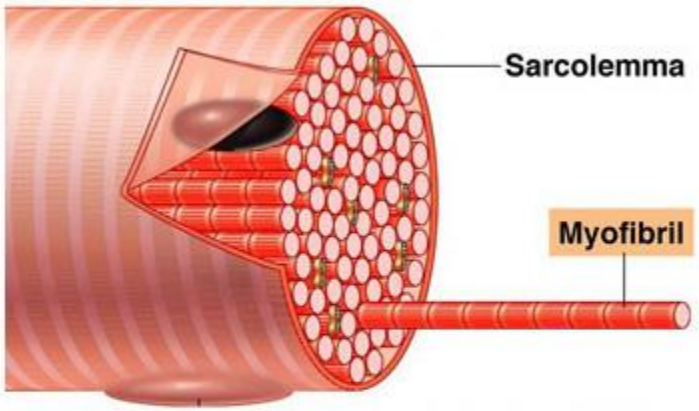

KEY
Stimulus
Receptor
Afferent path
Integrating center
Efferent path
Effector
Tissue response
Brain
CENTRAL NERVOUS SYSTEM (brain and spinal cord)
Spinal cord
Signal
Sensory receptors
stimulate
Sensory neurons (afferents)
Efferent neurons
Autonomic neurons
Somatic motor neurons
Sympathetic
Parasympathetic
control
control
communicate with
stimulate
control
• Smooth muscle
• Cardiac muscle
• Exocrine glands/cells
• Some endocrine glands/cells
• Some adipose tissue
Skeletal muscles
Signal
Neurons of enteric nervous system
Digestive tract
Tissue responses
Feedback

Diseases and Disorders of the Muscular System

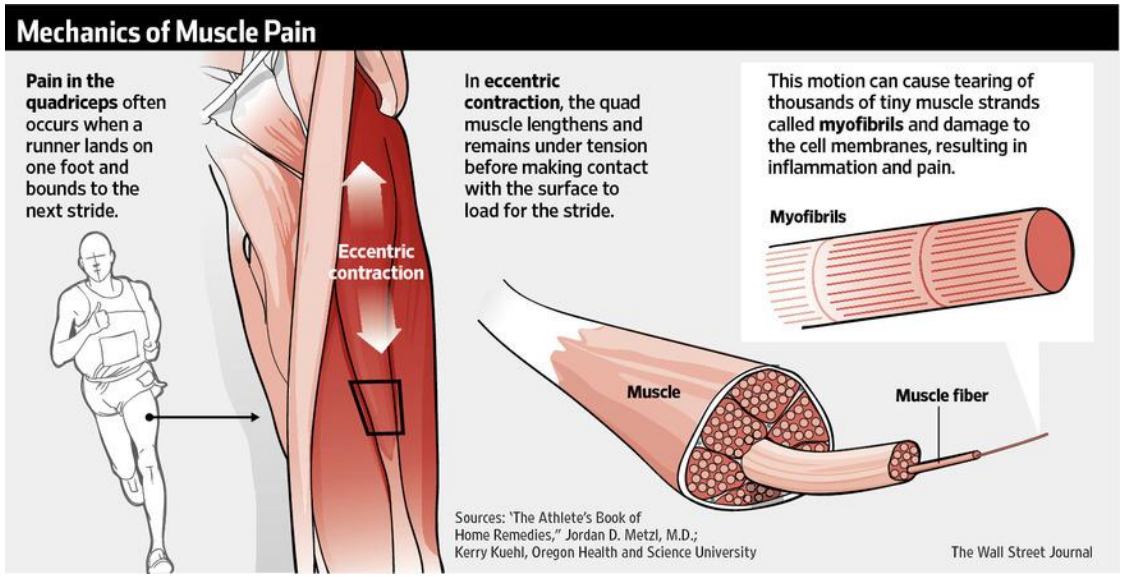
Disease	Description
Botulism	Affects the gastrointestinal tract and various muscle groups
Fibromyalgia	Fairly common condition that causes chronic pain primarily in joints, muscles, and tendons
Muscular Dystrophy	Inherited disorder characterized by muscle weakness and a loss of muscle tissue
Myasthenia gravis	Autoimmune condition in which patients experience muscle weakness

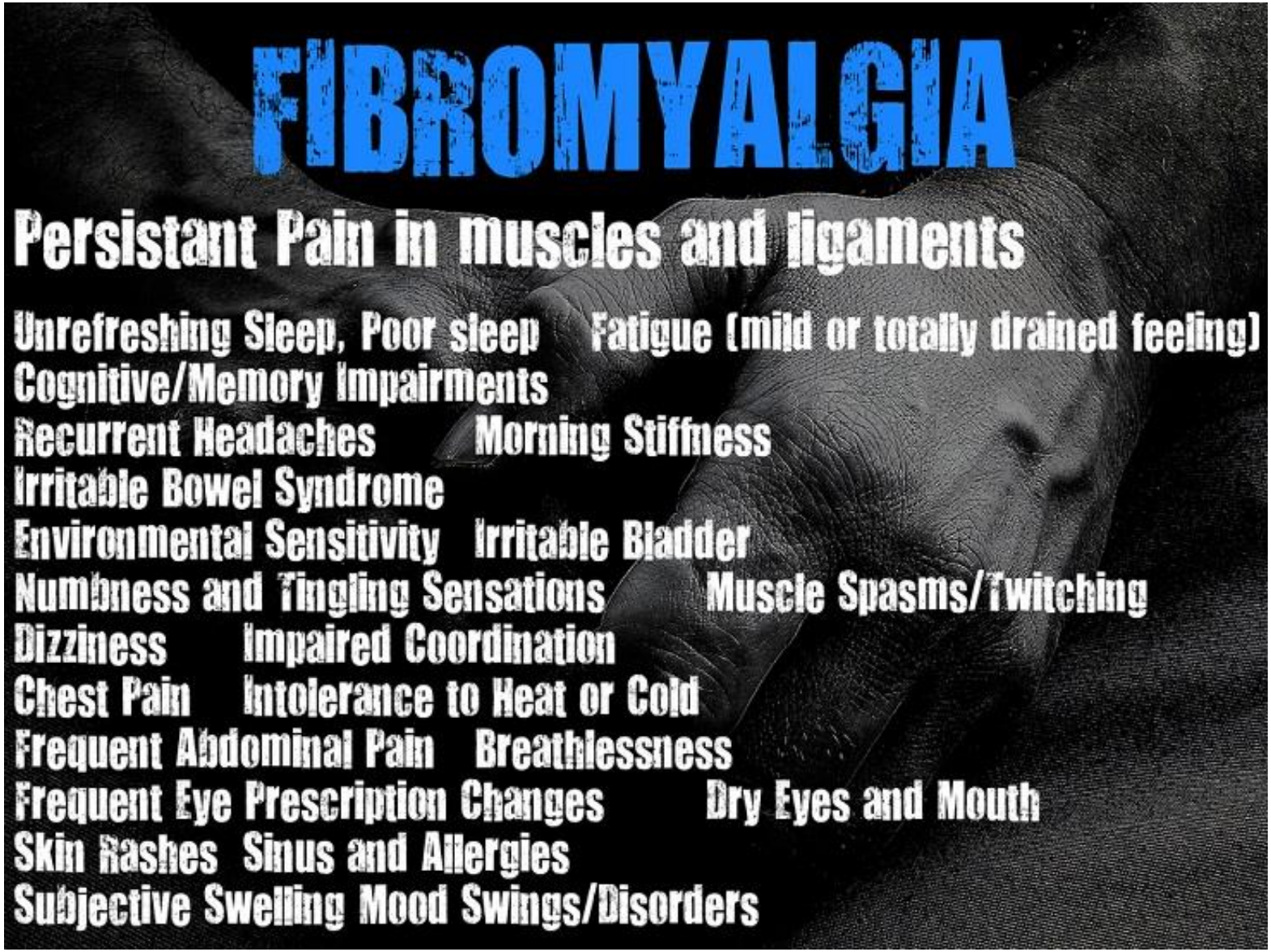
Diseases and Disorders of the Muscular System

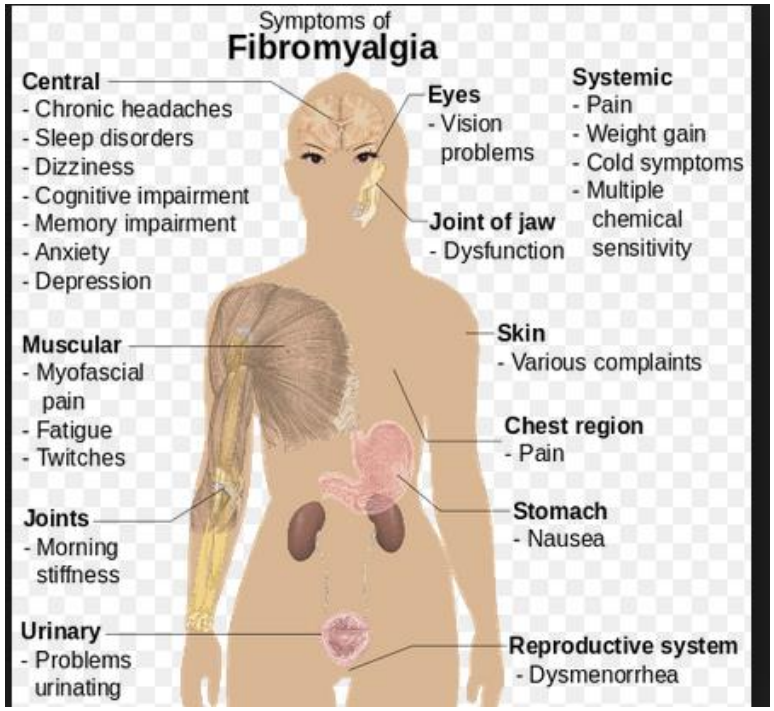
- **Myalgia: Muscle pain due to strain, tearing of muscle fibers. It also is a symptom of an immune response along with a fever.**
- **Myositis: Inflammation of muscle tissue due to injury or disease.**
- **Charley Horse (fibromyositis): Inflamation of muscle tissue and the tendons associated with that muscle due to injury (tear or severe bruising- contusion)**
- **Cramps: Painful, involuntary muscle spasms**

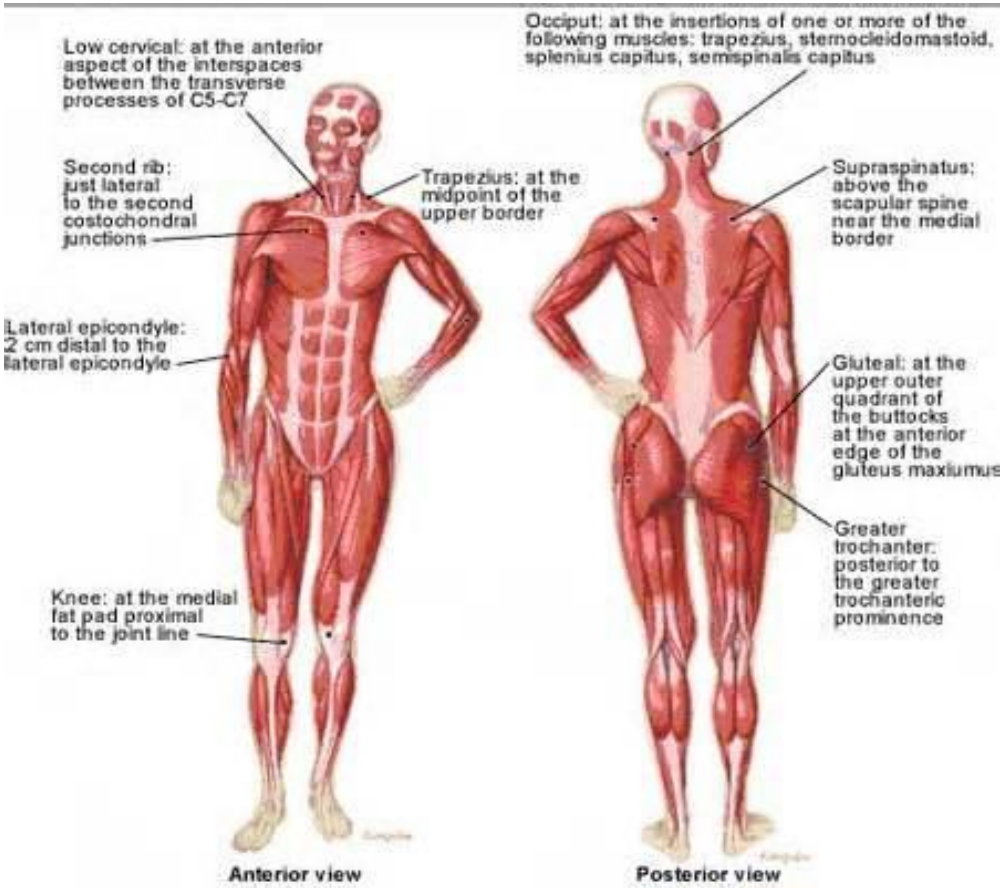


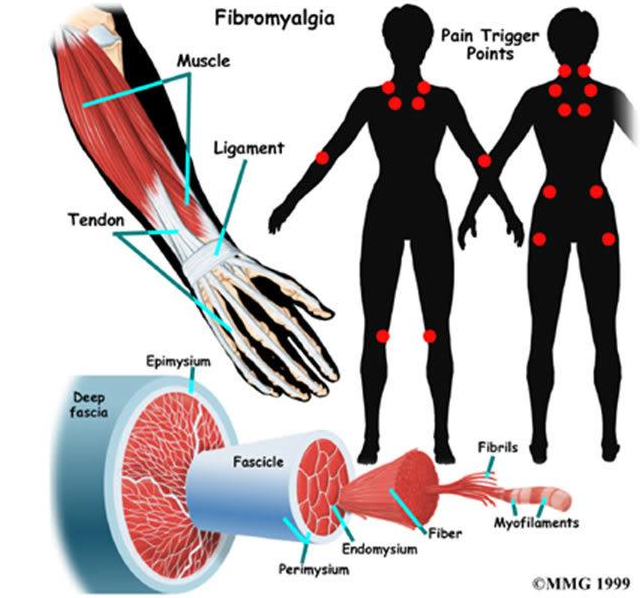
After intense exercise, damage to the muscle fibers and cell membrane (sarcolemma) may lead to inflammation, swelling and delayed-onset muscle soreness (DOMS)




FIBROMYALGIA
Persistant Pain in muscles and ligaments
Unrefreshing Sleep, Poor sleep
Fatigue (mild or totally drained feeling)
Cognitive/Memory Impairments
Recurrent Headaches
Morning Stiffness
Irritable Bowel Syndrome
Environmental Sensitivity
Irritable Bladder
Numbness and Tingling Sensations
Muscle Spasms/Twitching
Dizziness
Impaired Coordination
Chest Pain
Intolerance to Heat or Cold
Frequent Abdominal Pain
Breathlessness
Frequent Eye Prescription Changes
Dry Eyes and Mouth
Skin Rashes
Sinus and Allergies
Subjective Swelling
Mood Swings/Disorders

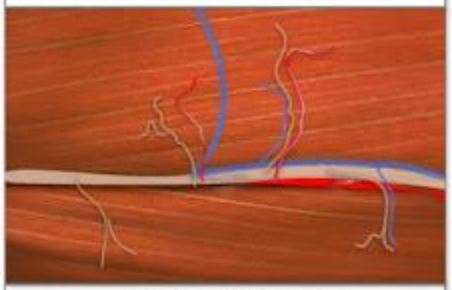

Symptoms of
Fibromyalgia
Central
- Chronic headaches
- Sleep disorders
- Dizziness
- Cognitive impairment
- Memory impairment
- Anxiety
- Depression
Eyes
- Vision problems
Joint of jaw
- Dysfunction
Systemic
- Pain
- Weight gain
- Cold symptoms
- Multiple chemical sensitivity
Muscular
- Myofascial pain
- Fatigue
- Twitches
Skin
- Various complaints
Chest region
- Pain
Joints
- Morning stiffness
Stomach
- Nausea
Urinary
- Problems urinating
Reproductive system
- Dysmenorrhea


Low cervical: at the anterior aspect of the interspaces between the transverse processes of C5-C7
Occiput: at the insertions of one or more of the following muscles: trapezius, sternocleidomastoid, splenius capitus, semispinalis capitus
Second rib: just lateral to the second costochondral junctions
Trapezius: at the midpoint of the upper border
Supraspinatus: above the scapular spine near the medial border
Lateral epicondyle: 2 cm distal to the lateral epicondyle
Gluteal: at the upper outer quadrant of the buttocks at the anterior edge of the gluteus maximus
Greater trochanter: posterior to the greater trochanteric prominence
Knee: at the medial fat pad proximal to the joint line
Anterior view
Posterior view

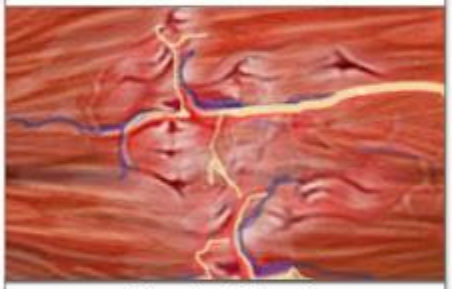

Fibromyalgia
Muscle
Ligament
Tendon
Pain Trigger Points
Epimysium
Deep fascia
Fascicle
Fibrils
Myofilaments
Fiber
Endomysium
Perimysium
©MMG 1999

Muscle Strain

Normal Muscle



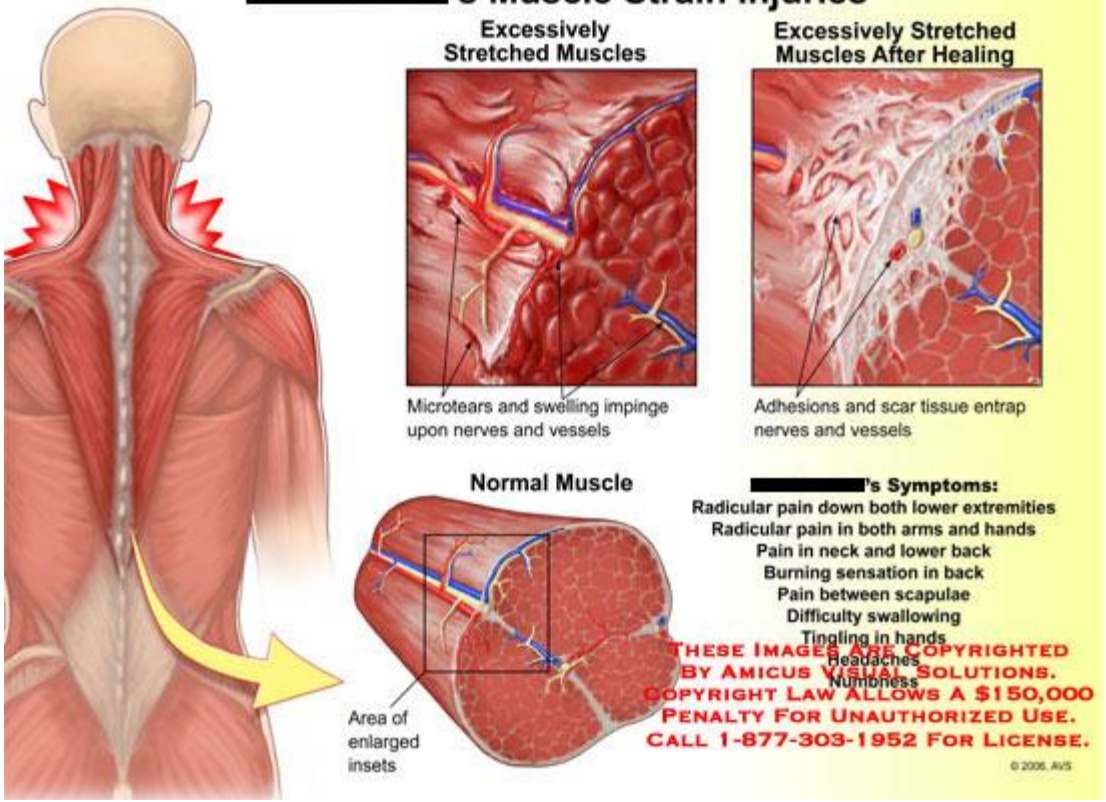
Strained Muscle

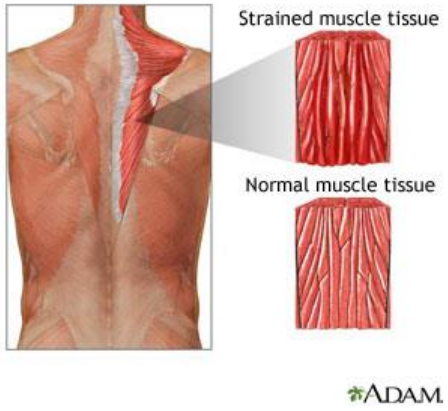


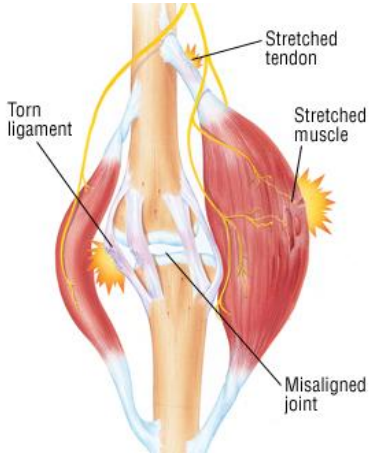
Healed Muscle

Scar tissue left on the muscle after healing restricts the muscle fibers, nerves, and vessels causing pain and leaving the muscle less flexible.

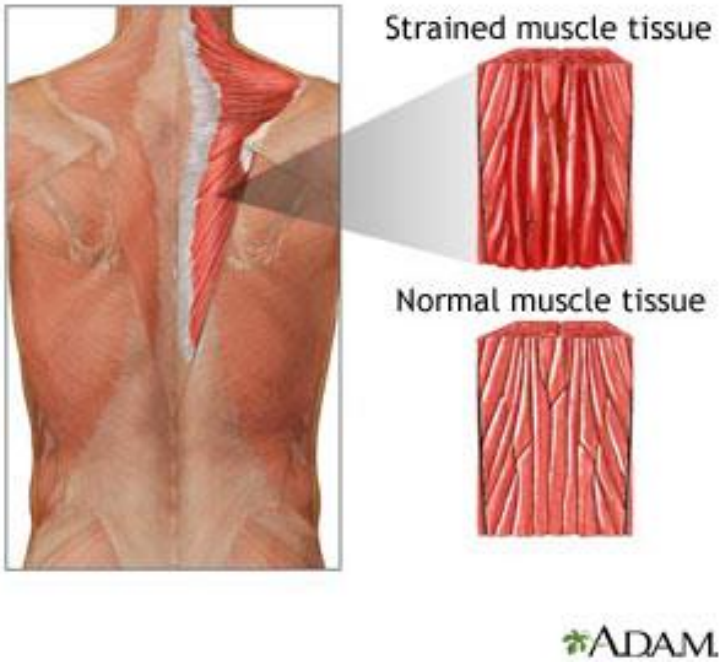
[redacted]'s Muscle Strain Injuries

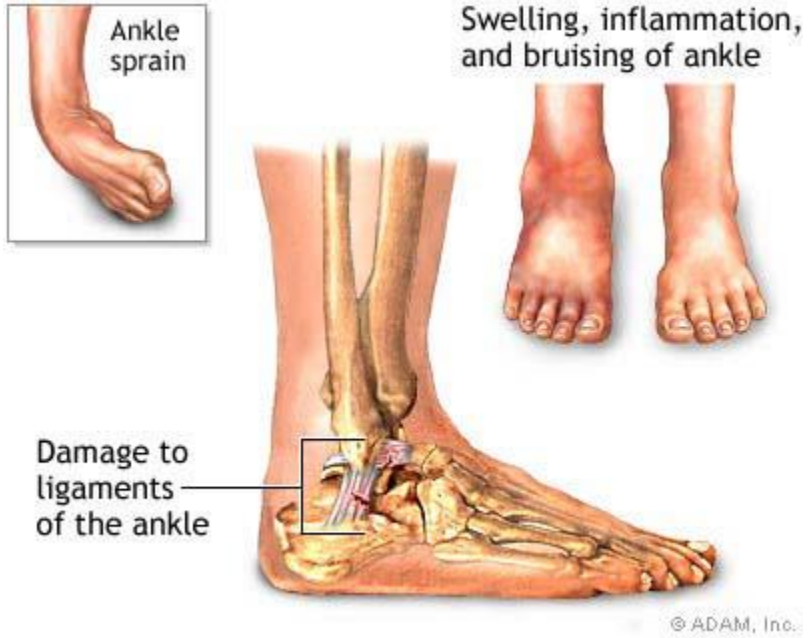




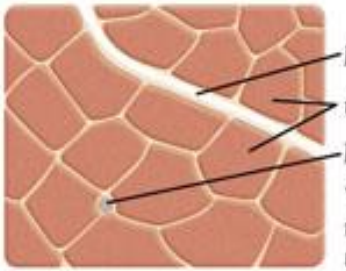


Starin vs sprain





Normal Muscle



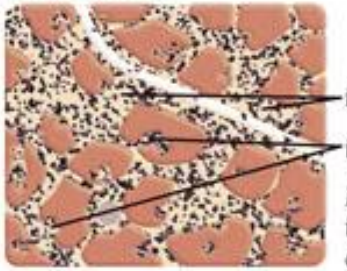
border of muscle bundle (fascicle)

normal muscle fibers

blood vessel

When normal muscle fibers are viewed under a microscope, they look like puzzle pieces that fit together neatly.

Polymyositis

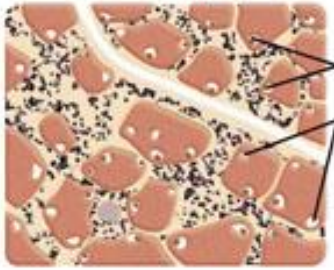


inflammatory cells

invasion of fibers by inflammatory cells

In polymyositis, inflammatory cells of the immune system invade previously healthy muscle cells, which become rounded and variable in size.

Inclusion-Body Myositis

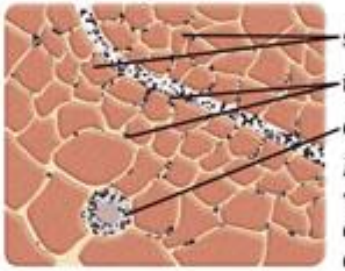


inclusion bodies

vacuoles

Inclusion-body myositis is characterized by muscle fibers that contain empty, bubble-like spaces (vacuoles) and clumps of cellular material (inclusion bodies). Inflammatory cells can be seen between the fibers.

Dermatomyositis



shrinkage (atrophy) of fibers near border of fascicle

inflammatory cells around fascicle and between fibers

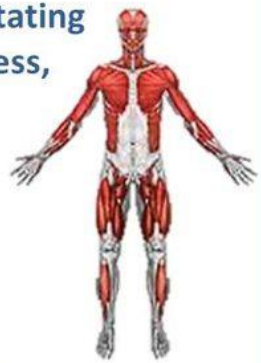
cuff of inflammatory cells around blood vessel

In DM, inflammatory cells are concentrated around blood vessels at the borders of the muscle fiber bundles (fascicles), and fibers in this region often shrink. Inflammatory cells can sometimes be seen forming a cuff around blood vessels.

Myositis = (my-oh-SIGH-tis)

A rare disease that causes debilitating muscle weakness, pain, soreness, inflammation, fatigue, and other symptoms.

Its cause is unknown.



Go to www.myositis.org

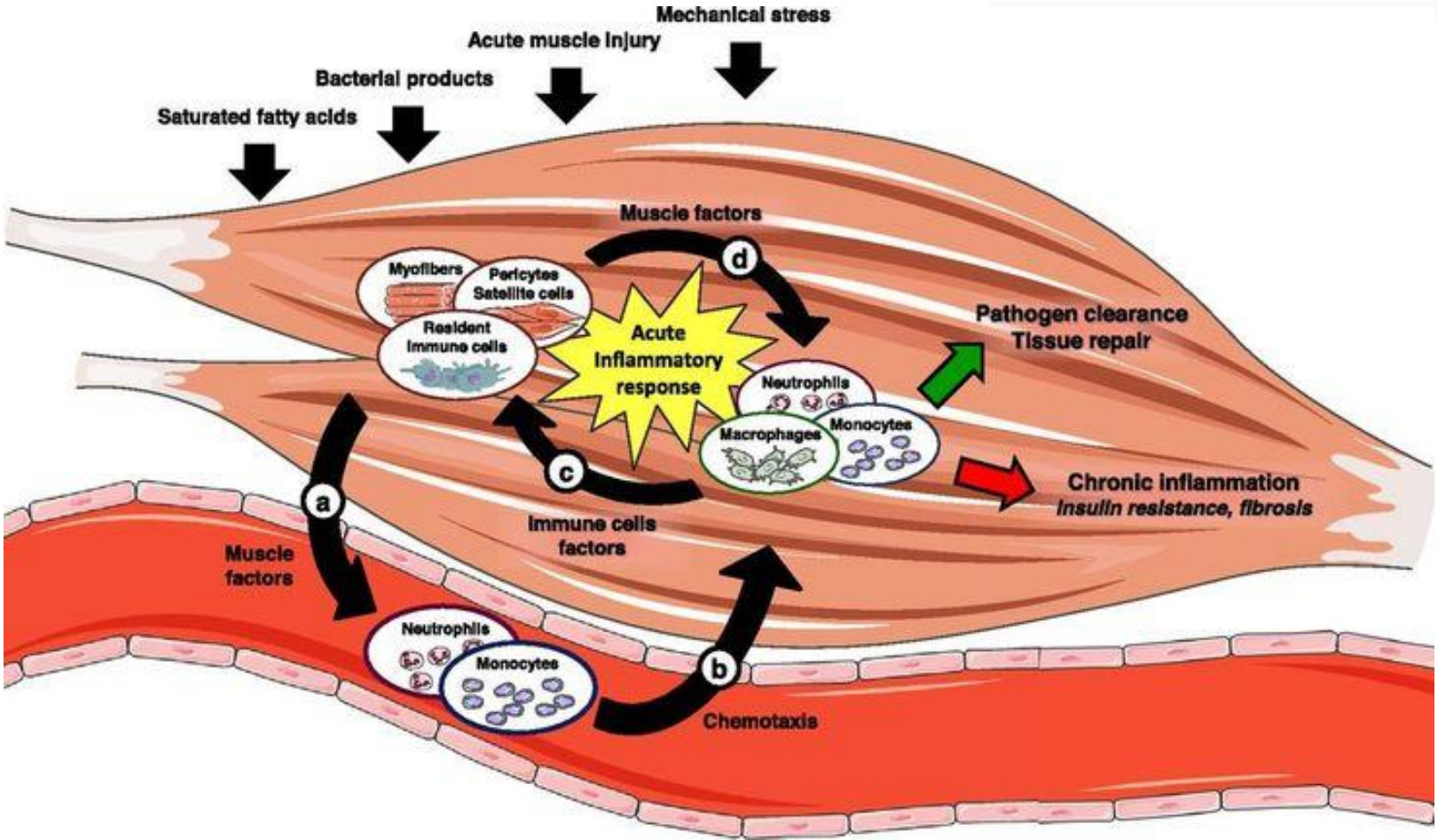
Symptoms of Myositis

- The main symptom of myositis is muscle weakness that may be detectable with testing
  - Muscle pain (myalgias)
  - Dermatomyositis, polymyositis
  - The weakness affects large muscle groups
    - including the neck, shoulders, hips, and back

Dermatomyositis

Causes of Myositis

- Myositis is caused by any condition that leads to inflammation in the muscles
- Myositis causes can be divided into several major categories:
  - Inflammatory conditions causing myositis
  - Myositis caused by microbial infection
  - Myositis caused by drugs
  - Myositis due to injury



SARCOPENIA

Endocrine
corticosteroids, GH, IGF-1
abnormal thyroid function
insulin resistance

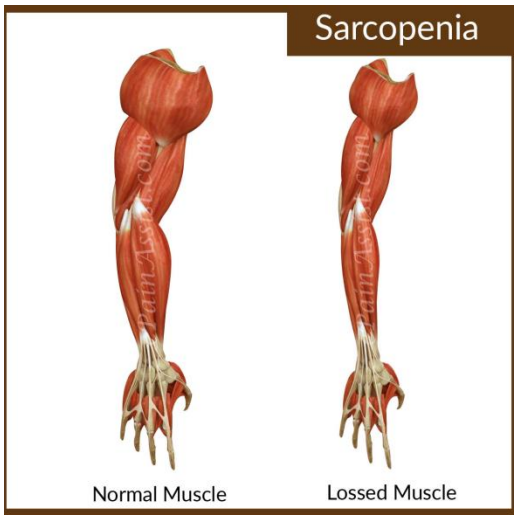
Age-related (Primary)
sex hormones
apoptosis
mitochondrial dysfunction

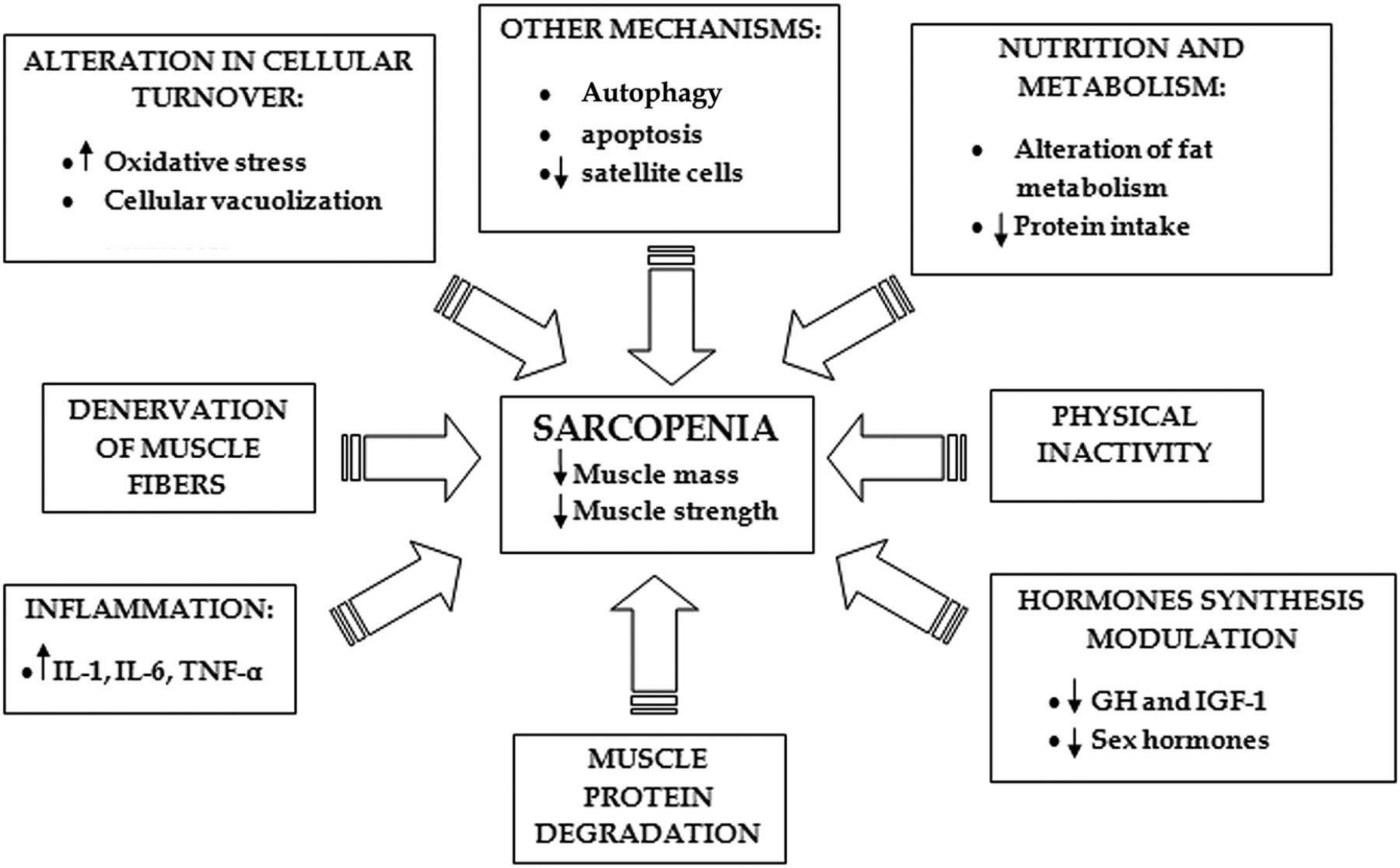
Neuro-degenerative diseases
motor neuron loss

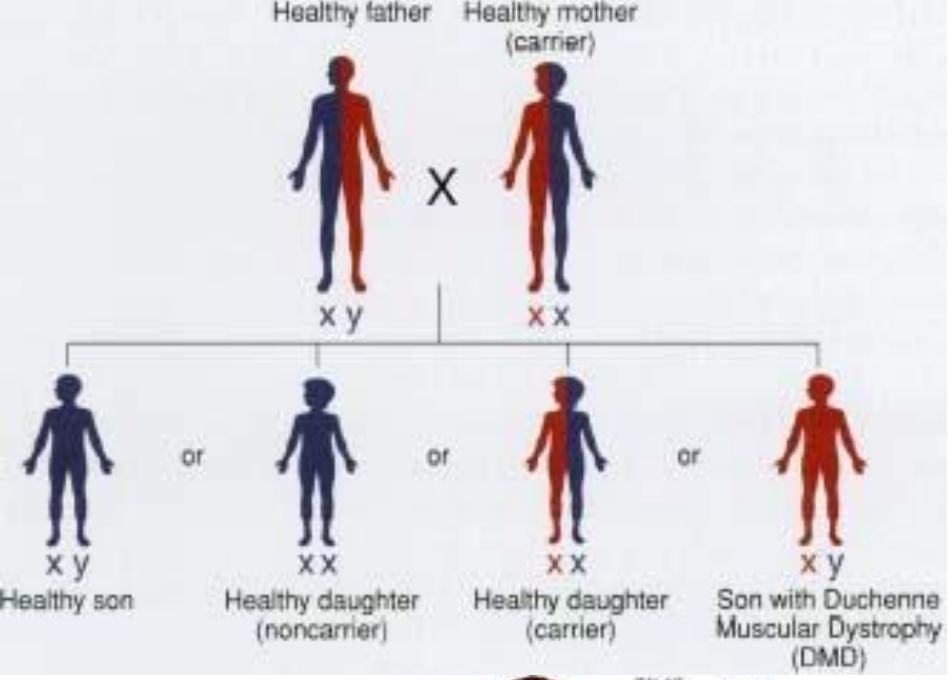
Disuse
immobility
physical inactivity
zero gravity

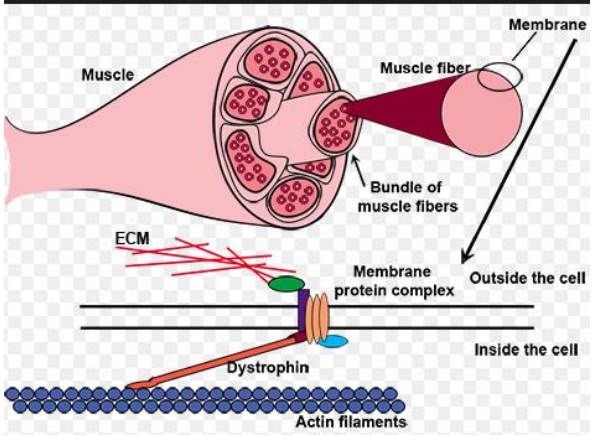
Inadequate nutrition / Malabsorption

Cachexia

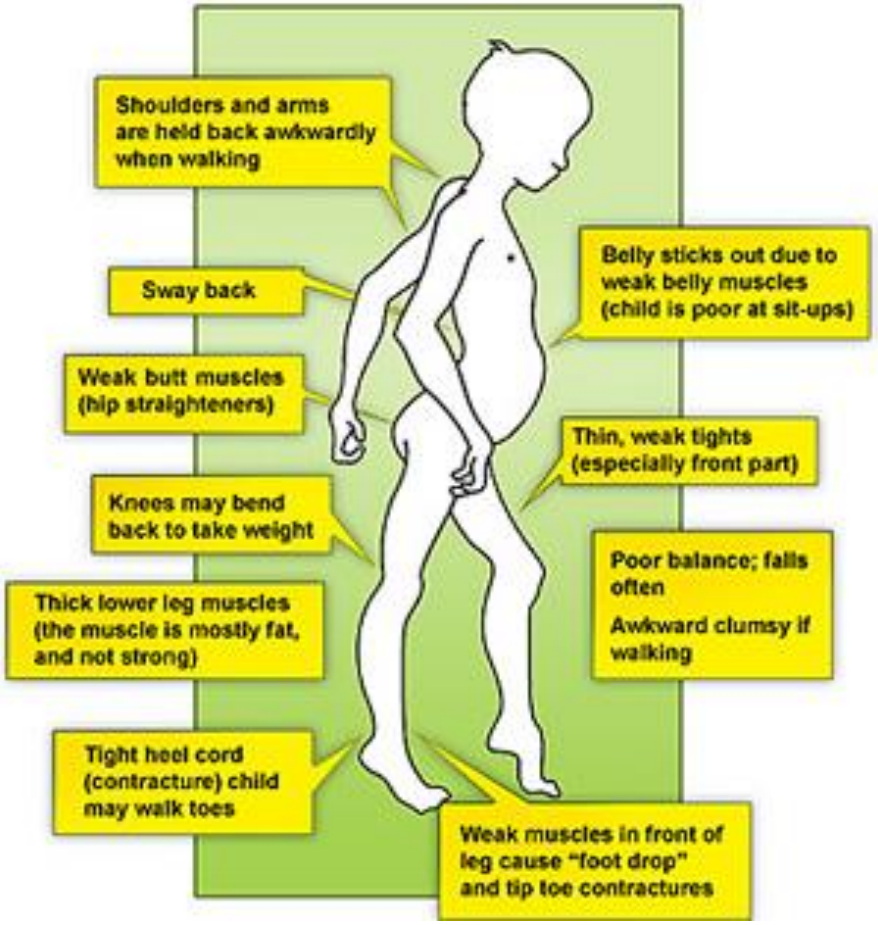


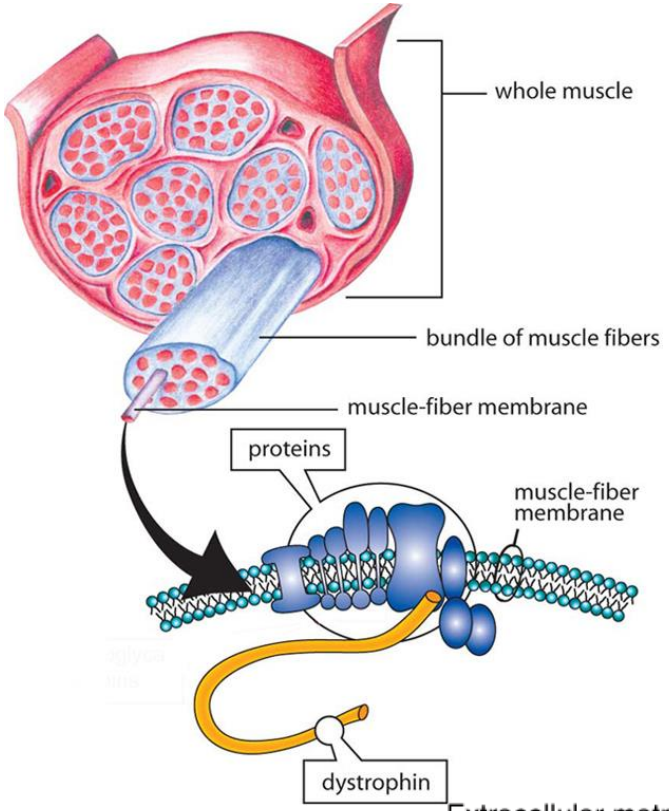

ALTERATION IN CELLULAR TURNOVER:
• ↑ Oxidative stress
• Cellular vacuolization
OTHER MECHANISMS:
• Autophagy
• apoptosis
• ↓ satellite cells
NUTRITION AND METABOLISM:
• Alteration of fat metabolism
• ↓ Protein intake
DENERVATION OF MUSCLE FIBERS
SARCOPENIA
↓ Muscle mass
↓ Muscle strength
PHYSICAL INACTIVITY
INFLAMMATION:
• ↑ IL-1, IL-6, TNF-α
MUSCLE PROTEIN DEGRADATION
HORMONES SYNTHESIS MODULATION
• ↓ GH and IGF-1
• ↓ Sex hormones

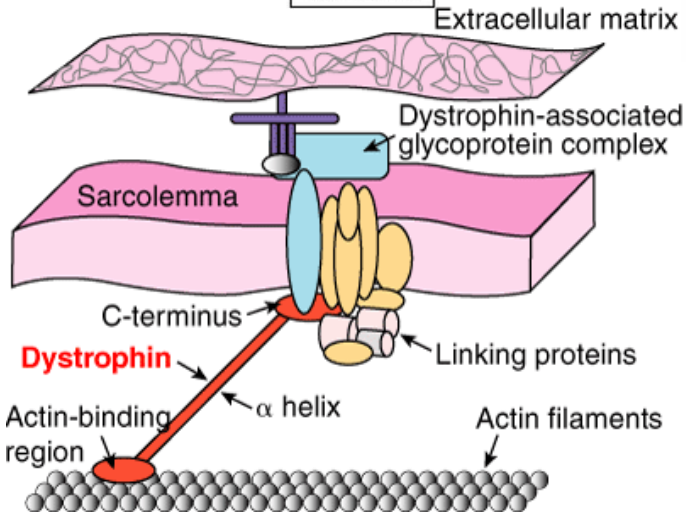

Healthy father
Healthy mother (carrier)
x
x y
x x
or
or
or
x y
Healthy son
x x
Healthy daughter (noncarrier)
x x
Healthy daughter (carrier)
x y
Son with Duchenne Muscular Dystrophy (DMD)


Membrane
Muscle
Muscle fiber
Bundle of muscle fibers
ECM
Membrane protein complex
Outside the cell
Inside the cell
Dystrophin
Actin filaments


2 years
8 years
15 years
Minimal or no symptoms
Severe crippling deformities and contractures
Progression with age
Weakness, especially of pelvic girdle muscles; marked lordosis; enlarged calves
Calf muscles usually but not always enlarged
Lordosis disappears when child sits

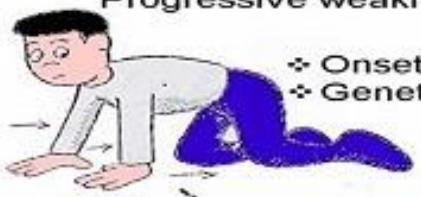

Shoulders and arms are held back awkwardly when walking
Sway back
Weak butt muscles (hip straighteners)
Knees may bend back to take weight
Thick lower leg muscles (the muscle is mostly fat, and not strong)
Tight heel cord (contracture) child may walk toes
Belly sticks out due to weak belly muscles (child is poor at sit-ups)
Thin, weak tights (especially front part)
Poor balance; falls often
Awkward clumsy if walking
Weak muscles in front of leg cause "foot drop" and tip toe contractures





MUSCULAR DYSTROPHY

Progressive weakness & wasting of muscles



- Onset 1 - 5 years old
- Genetic: primarily males
- history of motor development delay
- Gower's sign
- clumsiness
- frequent falls
- difficulty climbing stairs
- wadlling gait

- ambulation frequently impossible by age 12.
- as breathing muscles become more affected, life-threatening infections are common: this ussualy leads to death by age 15-18 years.

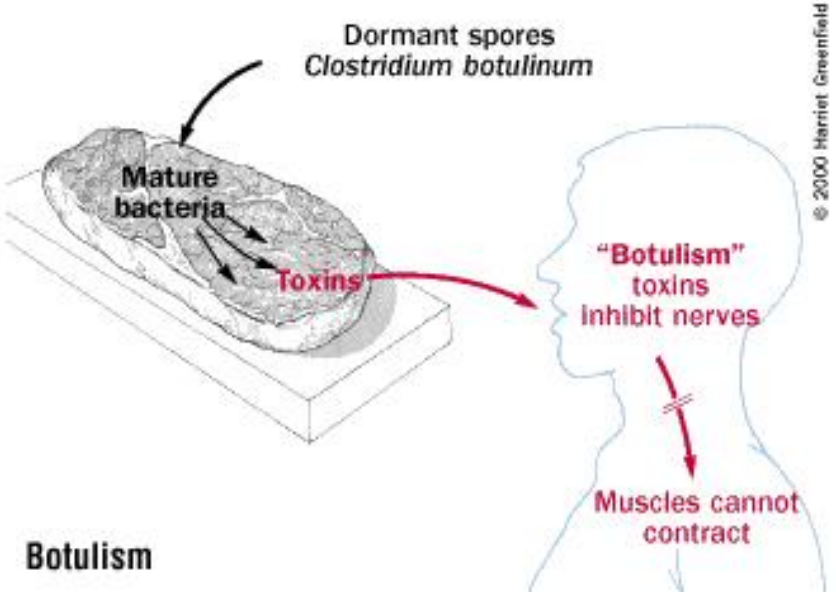
Nursing Considerations

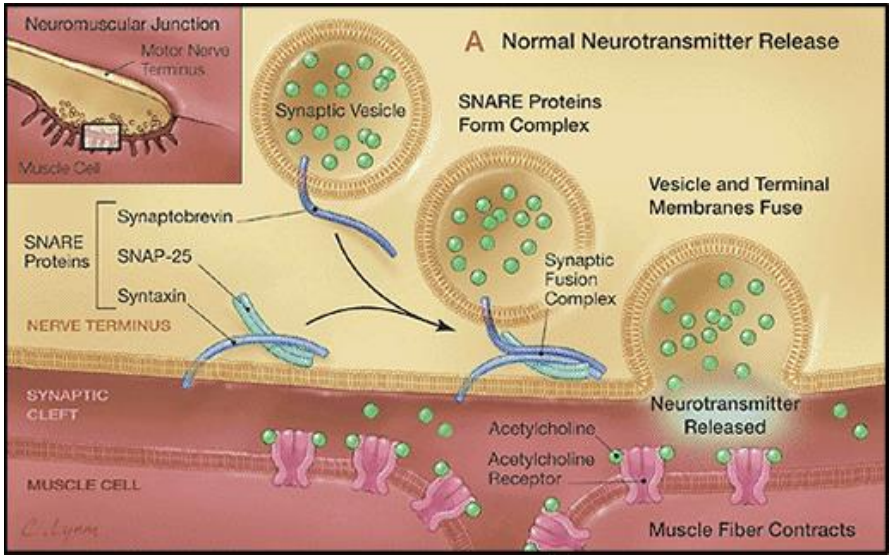
- fatigue
- mobility
- diet
- psychological effects

Clostridium botulinum

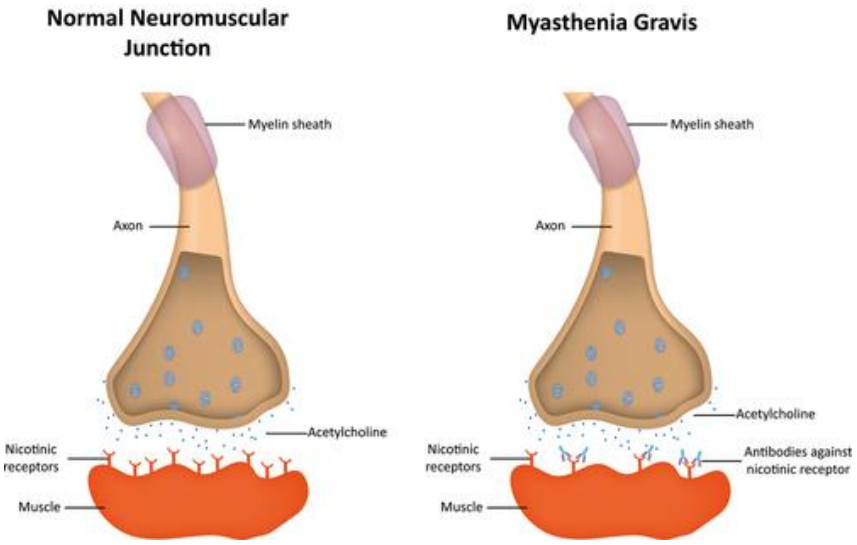
Causes 3 diseases

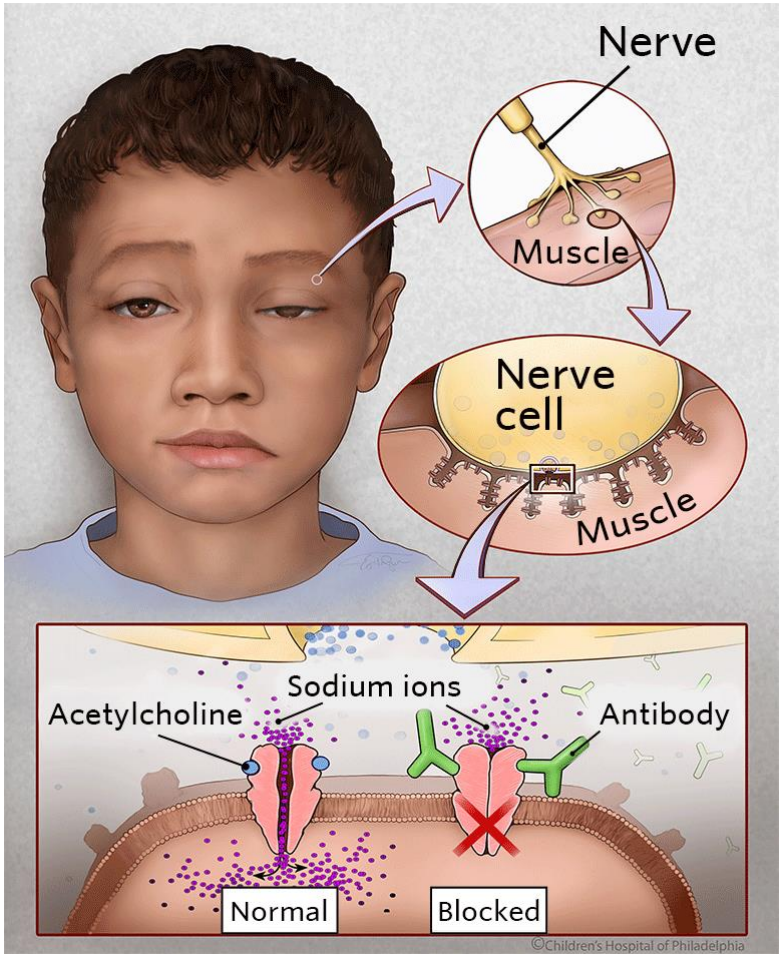
1. food poisoning
   - spores are in soil, may contaminate vegetables
   - improper canning does not kill spores & they germinate in the can producing botulinum toxin
   - toxin causes paralysis by preventing release of acetylcholine
2. infant botulism
   - caused by ingested spores that germinate & release toxin
3. wound botulism
   - spores enter wound & cause food poisoning symptoms





Myasthenia Gravis





SYMPTOMS

- **Eye muscles**
- Drooping of one or both eyelids (ptosis).
- Double vision (diplopia)
- **Face and throat muscles**
- Altered speaking(dyasarthria)
- Difficulty swallowing(dysphagia)
- Problems chewing
- Limited facial expressions
- **Neck and limb muscles**
- Weakness in arms, legs, neck, fingers etc.
- Weakness in the chest muscles sometimes
- occurs. If this is severe, myasthenic crisis
- may result .

A

- Exact cause unknown, though there is thought to be a strong genetic link.
- Prevalence is 1/200000, and is most commonly seen in younger women and older men.
- At ↑risk if Family history of autoimmune diseases, or if patient has any (e.g SLE, RA etc)

S+S

- Myasthenia Gravis has a relapsing/remitting course.
- Symptoms generally best in the morning/after a rest.
- Fatigue
- Weakness of muscles → Ptosis, Diplobia, Dysphagia, Dysarthria, Dysphonia
  Weak facial muscles, Weak Shoulders/thighs,
  Weak neck/trunk muscles, weak Respiratory muscles
- Limb Reflexes → Normal or Brisk
- Muscle wasting → Only in severe/ Prolonged disease

P

- IgG autoantibodies produced against the Postsynaptic acetylcholine receptors in neuromuscular junctions.
- Associated disease of the thymus (75% get hyperplasia of thymus, 10% get a thymoma)

I

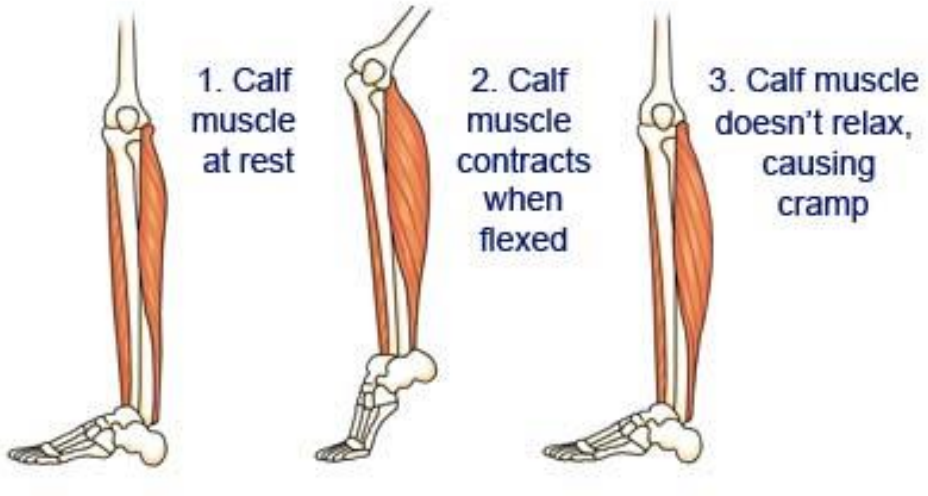
- Blood Tests → Serum acetylcholine receptor antibodies and other autoantibodies.
- Tensilon Test → Injection of Edrophionium and Atropine → Sudden symptomatic improvement.
- Electromyography → Fatigue following repeated electrical stimulation of muscle.
  → 'Jitter' found on Single Fibre Electrode.
- Thymus imaging → To check for hyperplasia.
- Spirometry → To monitor respiratory muscles.

T

- Oral acetylcholinesterase inhibitors (e.g Pyridostigmine) to ↓breakdown of acetylcholine
- Immunosupression → Corticosteroids usually, but steroid sparing agents can be used.
- Immunomodulatory agents
- In acute crises IV immunoglobulin or Plasmapheresis used.
- Thymectomy.

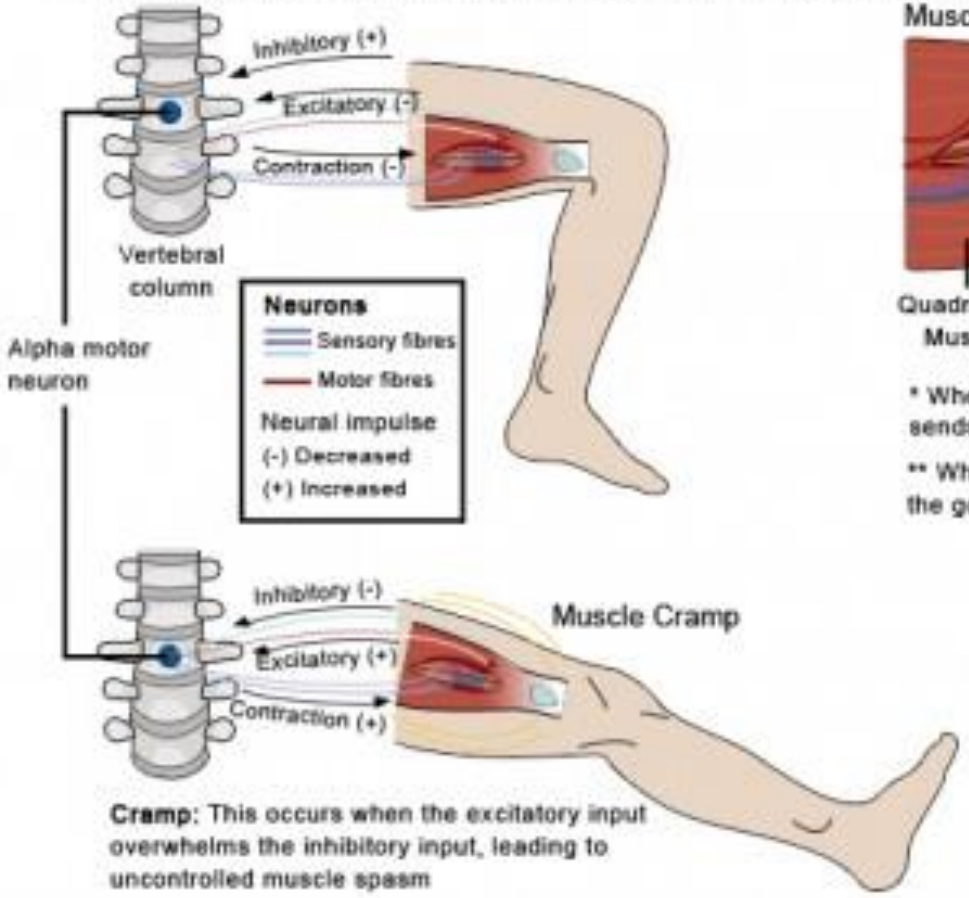
Muscle cramps

Muscle cramps can have many causes, such as dehydration, not enough blood flowing to the muscle, or being tired.



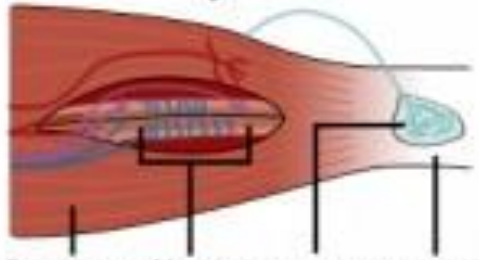
The Neuromuscular Theory of Muscle Cramps

Evidence suggests that muscles cramp up when the balance between excitatory and inhibitory input to motor neurons in the spine is obstructed. Many things can affect this balance, such as muscle fatigue and muscle injury.



Cramp: This occurs when the excitatory input overwhelms the inhibitory input, leading to uncontrolled muscle spasm

Muscle Anatomy

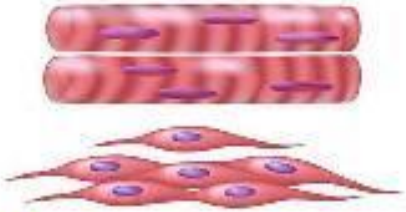


* When the muscle is stretched, the spindle sends a signal to contract (excitatory signal)

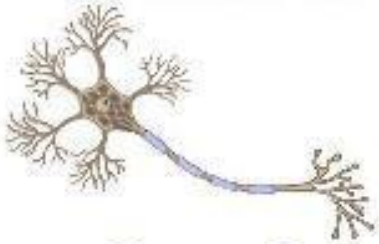
** When the muscle is under tension, the golgi sends a signal to relax (inhibitory signal)

Cramps in muscle cells caused by hyperventilation

Normal breathing pattern: 6 L/min,
12 breaths/min, 40 mm Hg aCO2

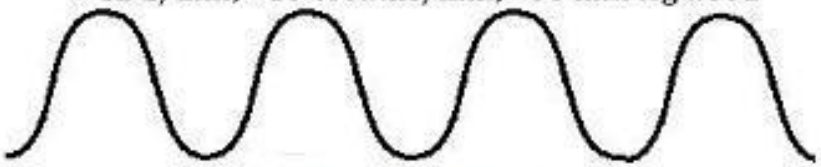


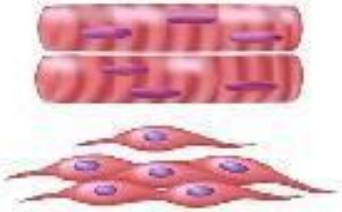
Muscle cells are relaxed
and well oxygenated



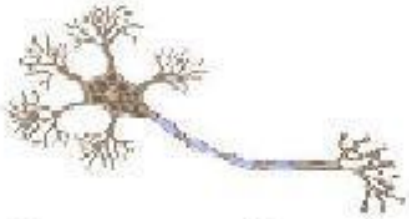
Nerve cells are calm and have
high excitability threshold

Ineffective breathing pattern (hyperventilation):
>12 L/min, >18 breaths/min, <35 mm Hg aCO2





Muscle cells are tense, constricted
(spasmodic) and possibly hypoxic



Nerve cells are irritable and over-excited
due to low threshold of excitability

www.NormalBreathing.com

Thank you