Muscle Physiology

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There are four characteristics associated with muscle tissue:

- Excitability - Tissue can receive & respond to stimulation
- Contractility - Tissue can shorten & thicken
- Extensibility - Tissue can lengthen
- Elasticity - After contracting or lengthening, tissue always wants to return to its resting state

The characteristics of muscle tissue enable it to perform some important functions, including:

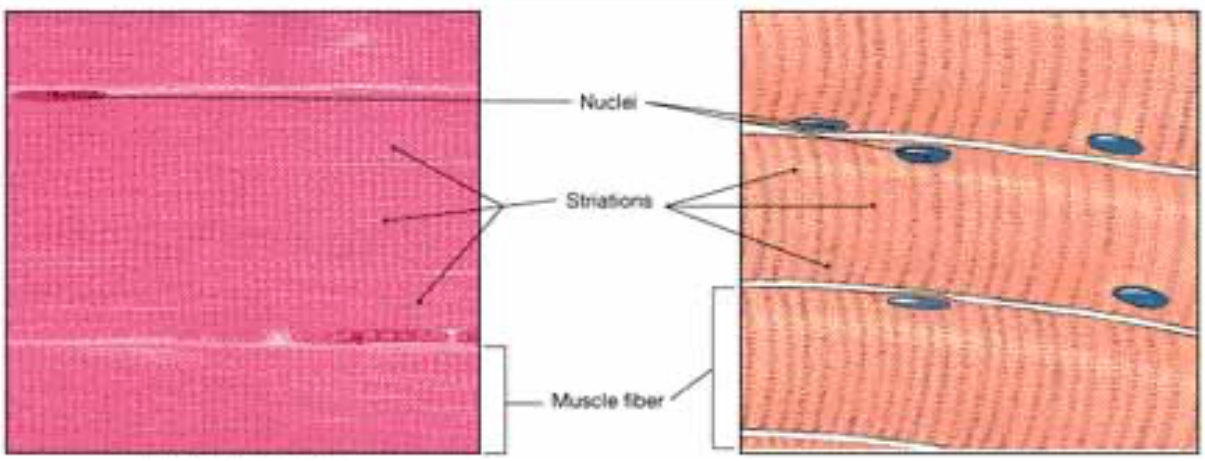
- Movement – both voluntary & involuntary
- Maintaining posture
- Supporting soft tissues within body cavities
- Guarding entrances & exits of the body
- Maintaining body temperature

Types of muscle tissue:

- Skeletal
- Cardiac
- Smooth (Visceral)

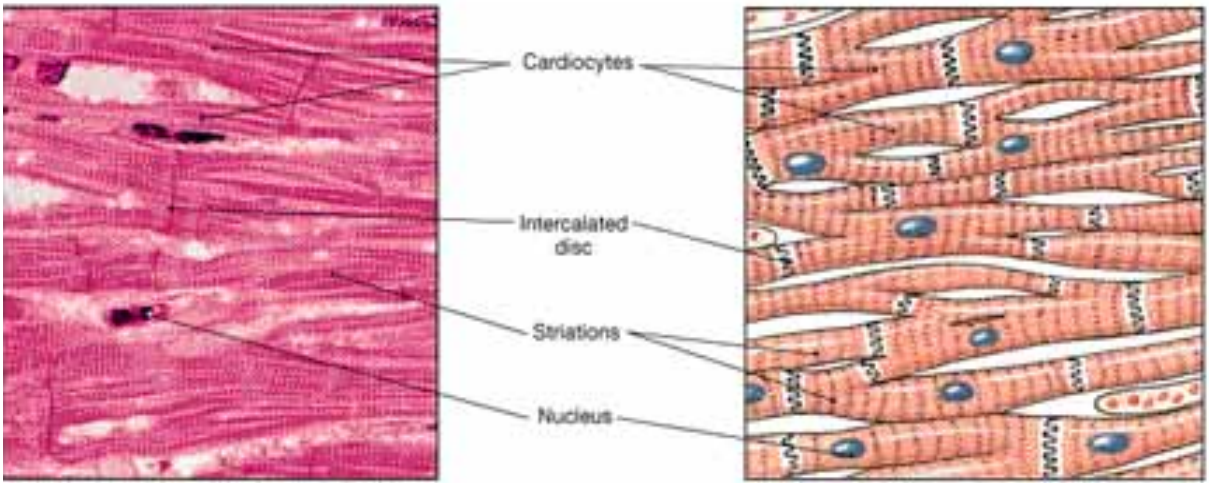
Skeletal muscle tissue

- Associated with & attached to the skeleton
- Under our conscious (voluntary) control
- Microscopically the tissue appears striated
- Cells are long, cylindrical & multinucleate



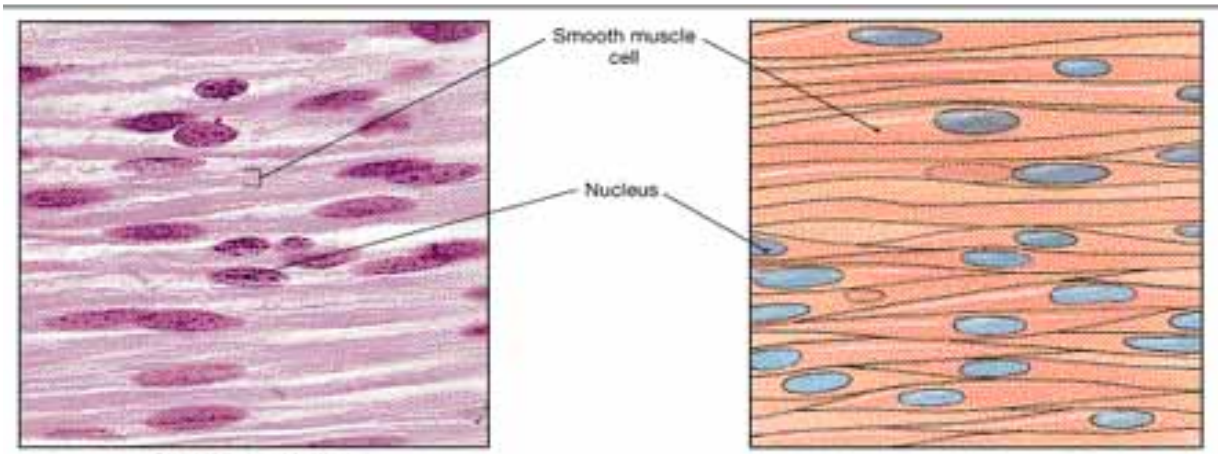
Cardiac muscle tissue

- Makes up myocardium of heart
- Unconsciously (*involuntarily*) controlled
- Microscopically appears *striated*
- Cells are short, branching & have a single nucleus
- Cells connect to each other at *intercalated discs*

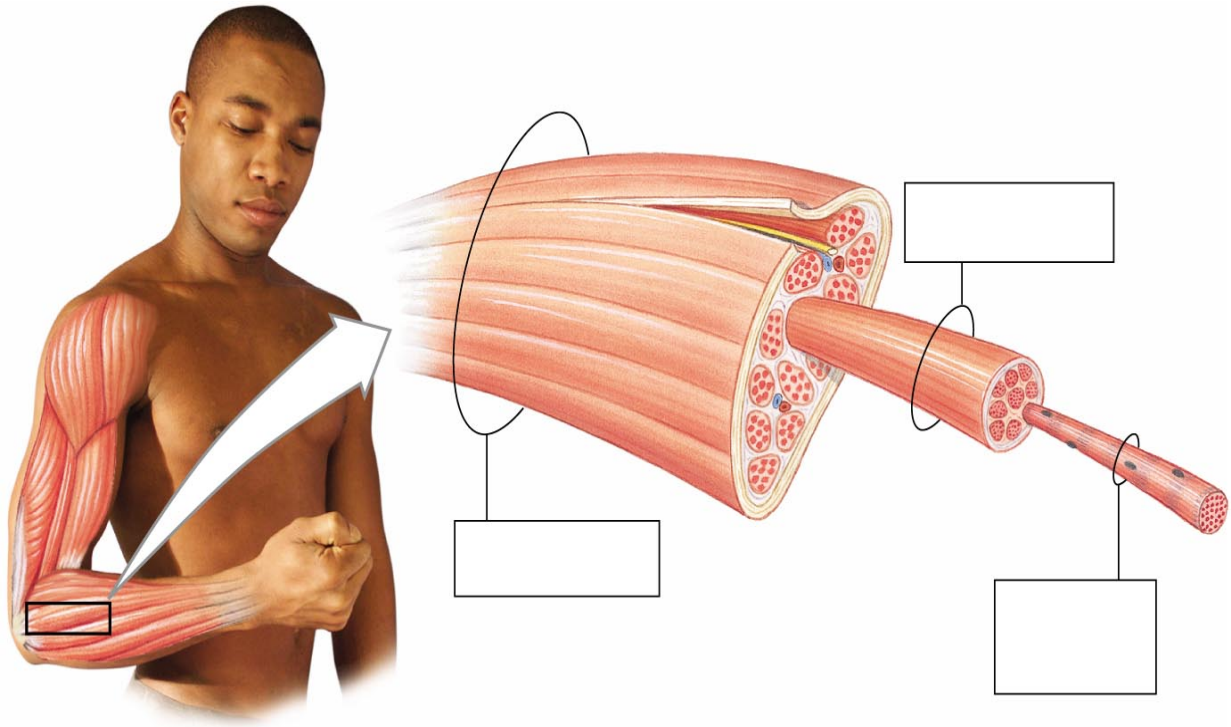


Smooth (visceral) muscle tissue

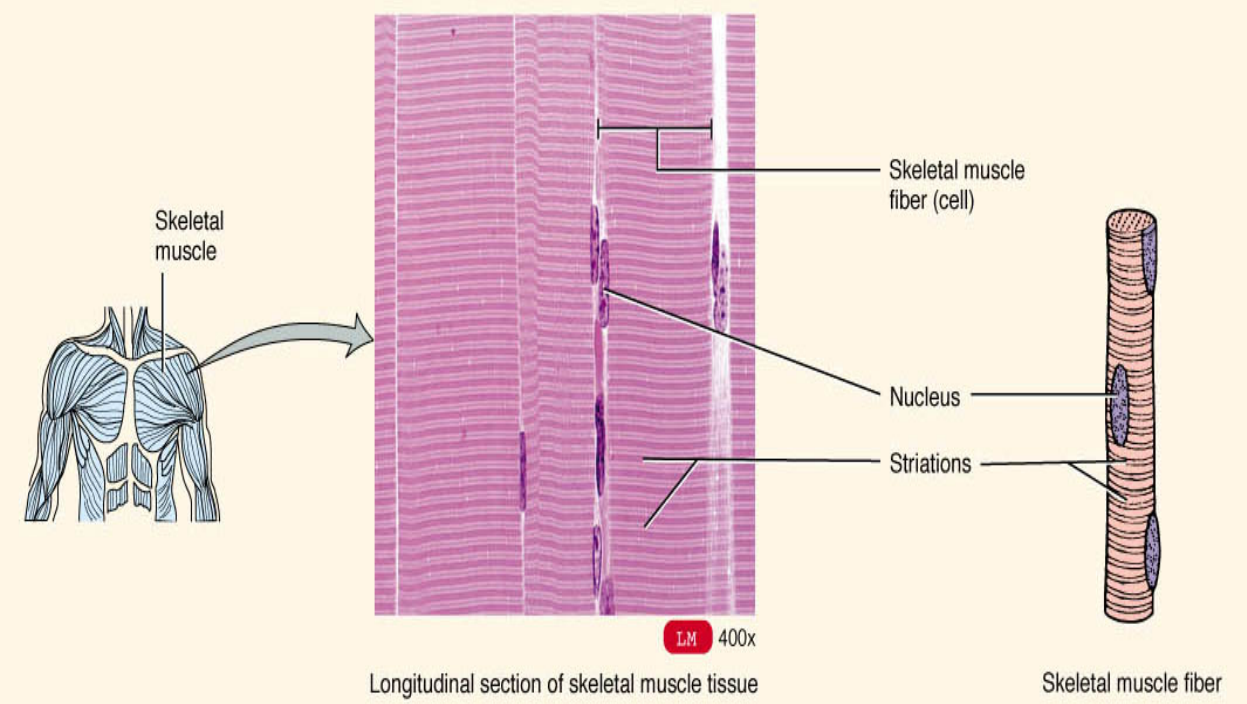
- Makes up walls of organs & blood vessels
- Tissue is *non-striated* & *involuntary*
- Cells are short, spindle-shaped & have a single nucleus
- Tissue is extremely extensible, while still retaining ability to contract

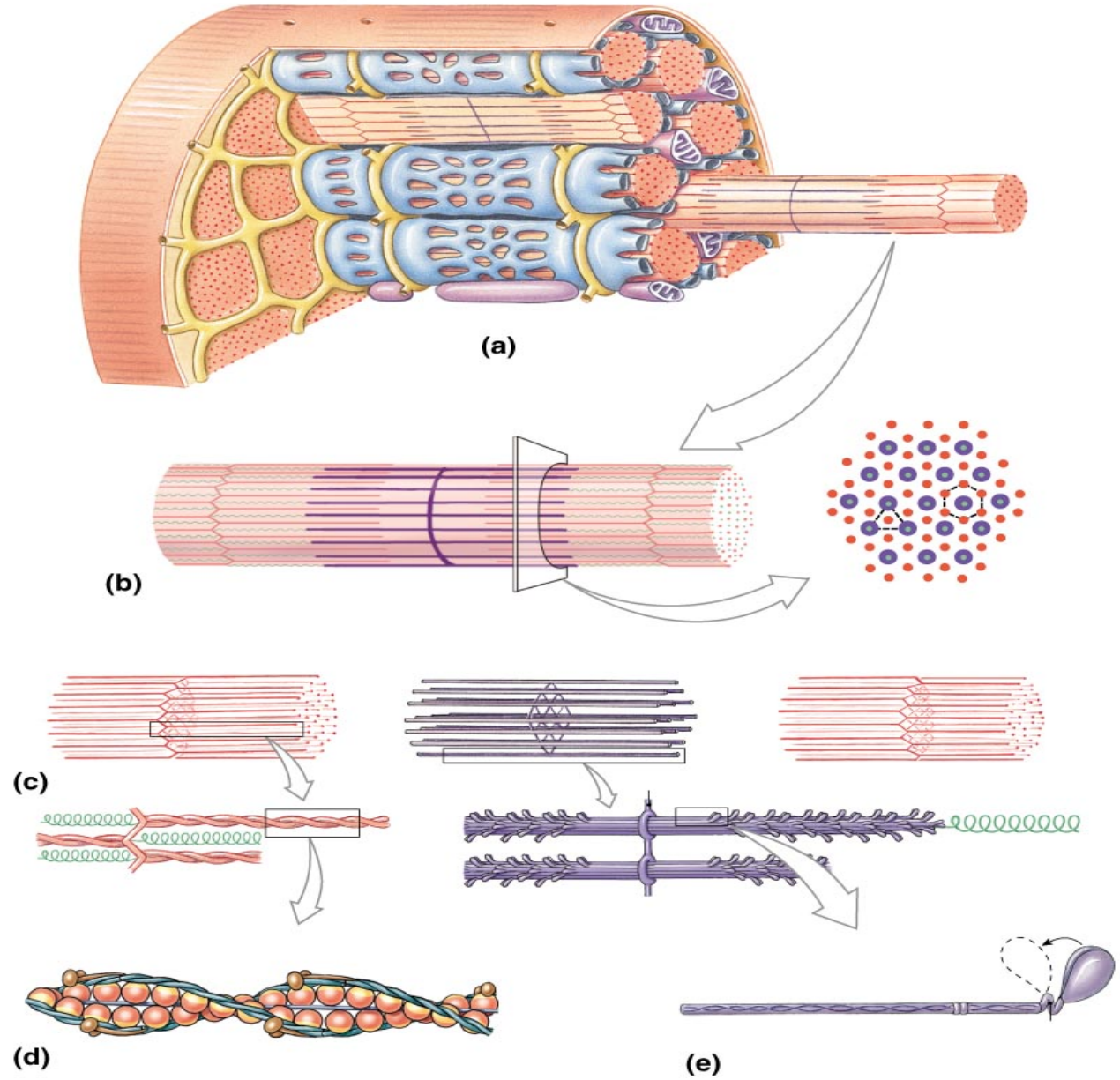


Anatomy of Skeletal Muscles



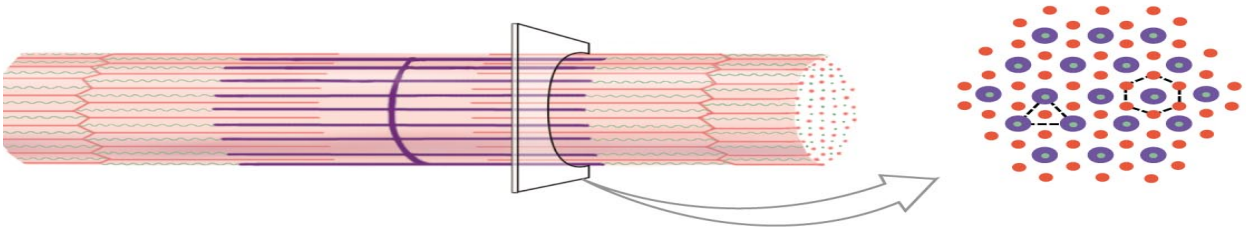
Microanatomy of a Muscle Fiber (cell)

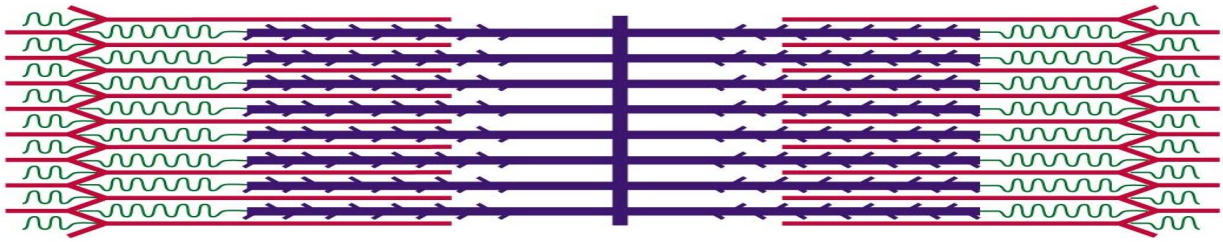


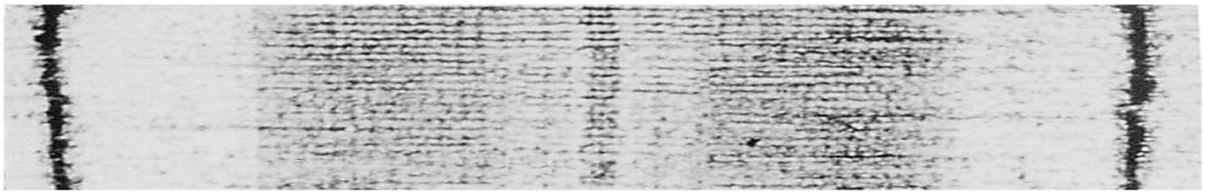


Thin Filament **Thick Filament**

Sarcomere







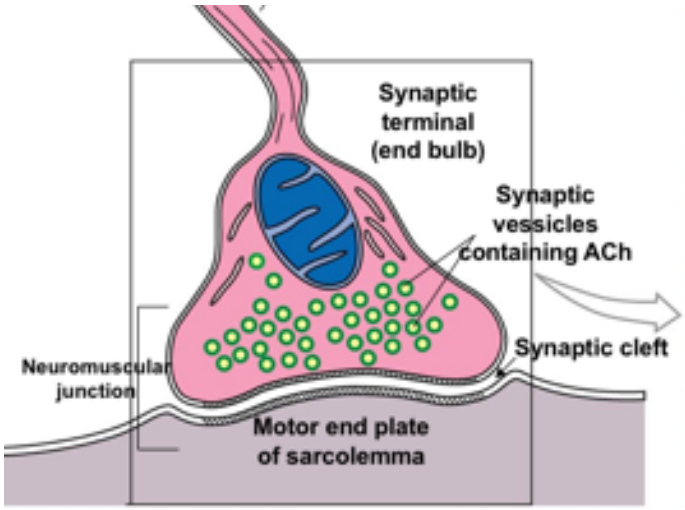
Sliding Filament Theory

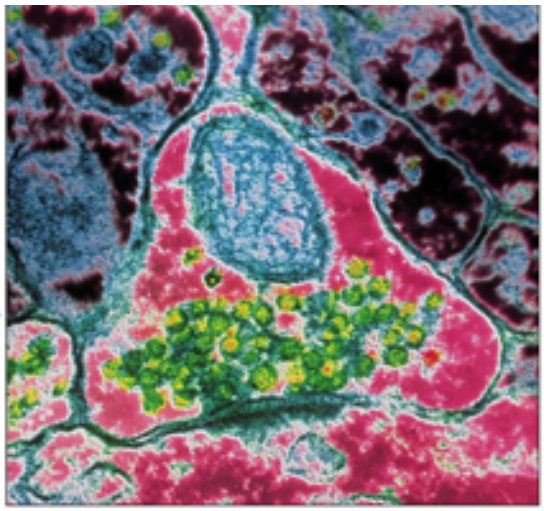
- Myosin heads attach to actin molecules (at binding (active) site)
- Myosin “pulls” on actin, causing thin myofilaments to slide across thick myofilaments, towards the center of the sarcomere
- Sarcomere shortens, I bands get smaller, H zone gets smaller, & zone of overlap increases
- As sarcomeres shorten, myofibril shortens. As myofibrils shorten, so does muscle fiber
- Once a muscle *fiber* begins to contract, it will contract maximally
- This is known as the “all or none” principle

Physiology of skeletal muscle contraction

- Skeletal muscles require stimulation from the nervous system in order to contract
- Motor neurons are the cells that cause muscle fibers to contract

Neuromuscular Junction





Overview of Events at the Neuromuscular Junction

- An *action potential (AP)*, an electrical impulse, travels down the axon of the motor neuron to the end bulbs (synaptic terminals)
- The AP causes the synaptic vesicles to fuse with the end bulb membrane, resulting in the release of Acetylcholine (ACh) into the synaptic cleft
- ACh diffuses across the synaptic cleft & binds to ACh receptors on the motor end plate
- The binding of ACh to its receptors causes a new AP to be generated along the muscle cell membrane
- Immediately after it binds to its receptors, Ach will be broken down by Acetylcholinesterase (AChE) – an enzyme present in the synaptic cleft

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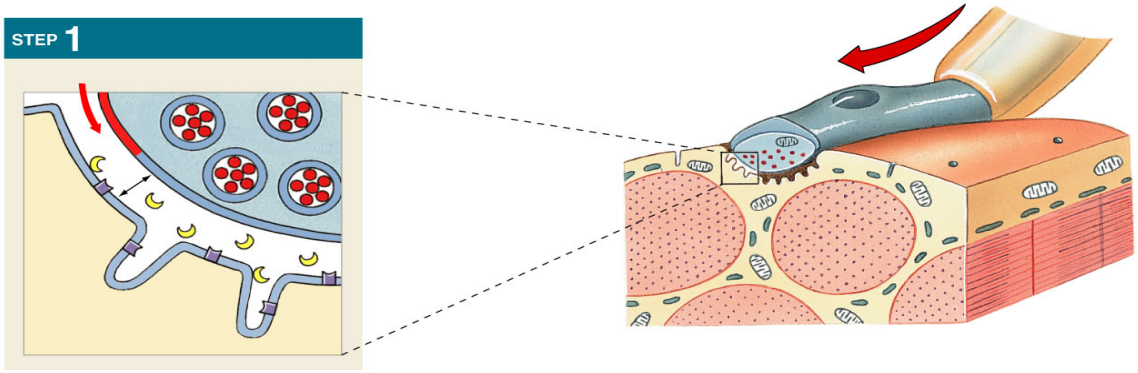

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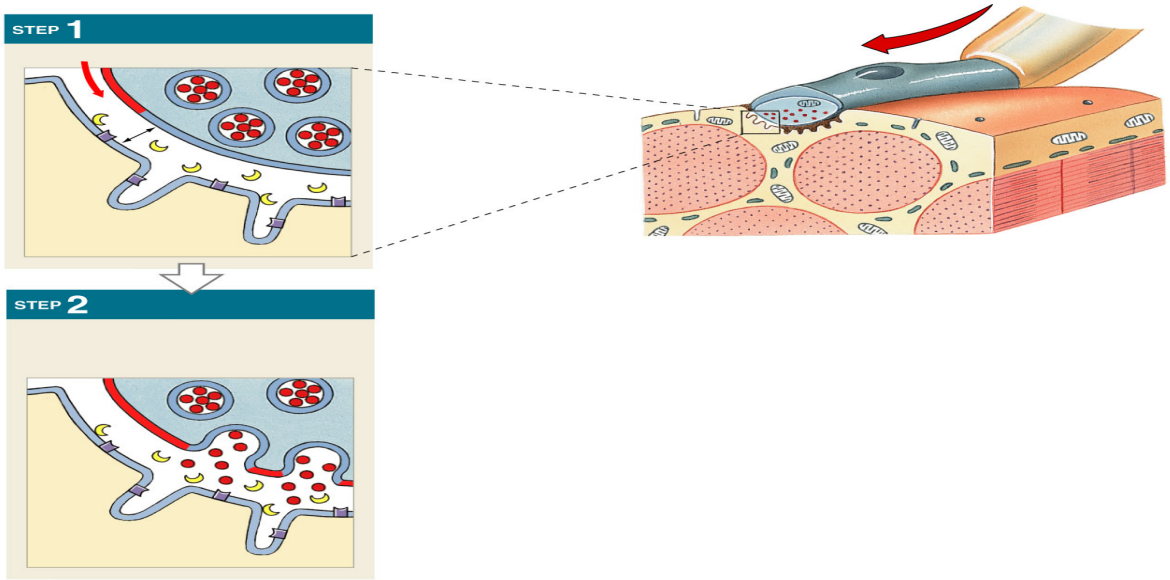
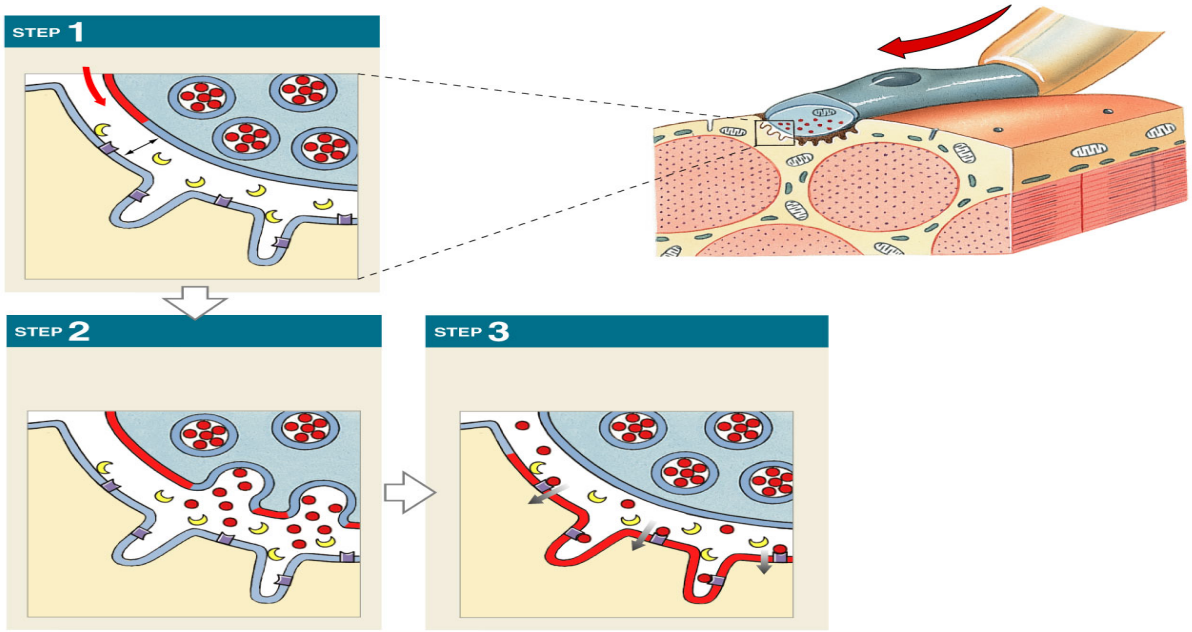
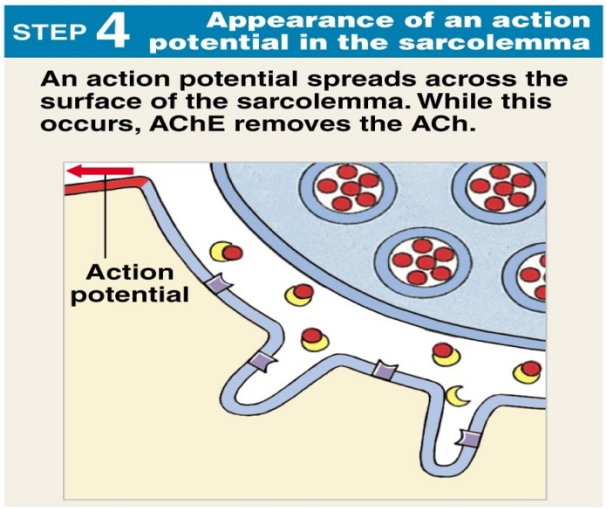


ACh diffuses across the synaptic cleft & binds to ACh receptors on the motor end plate





The binding of ACh to its receptors causes a new AP to be generated along the muscle cell membrane

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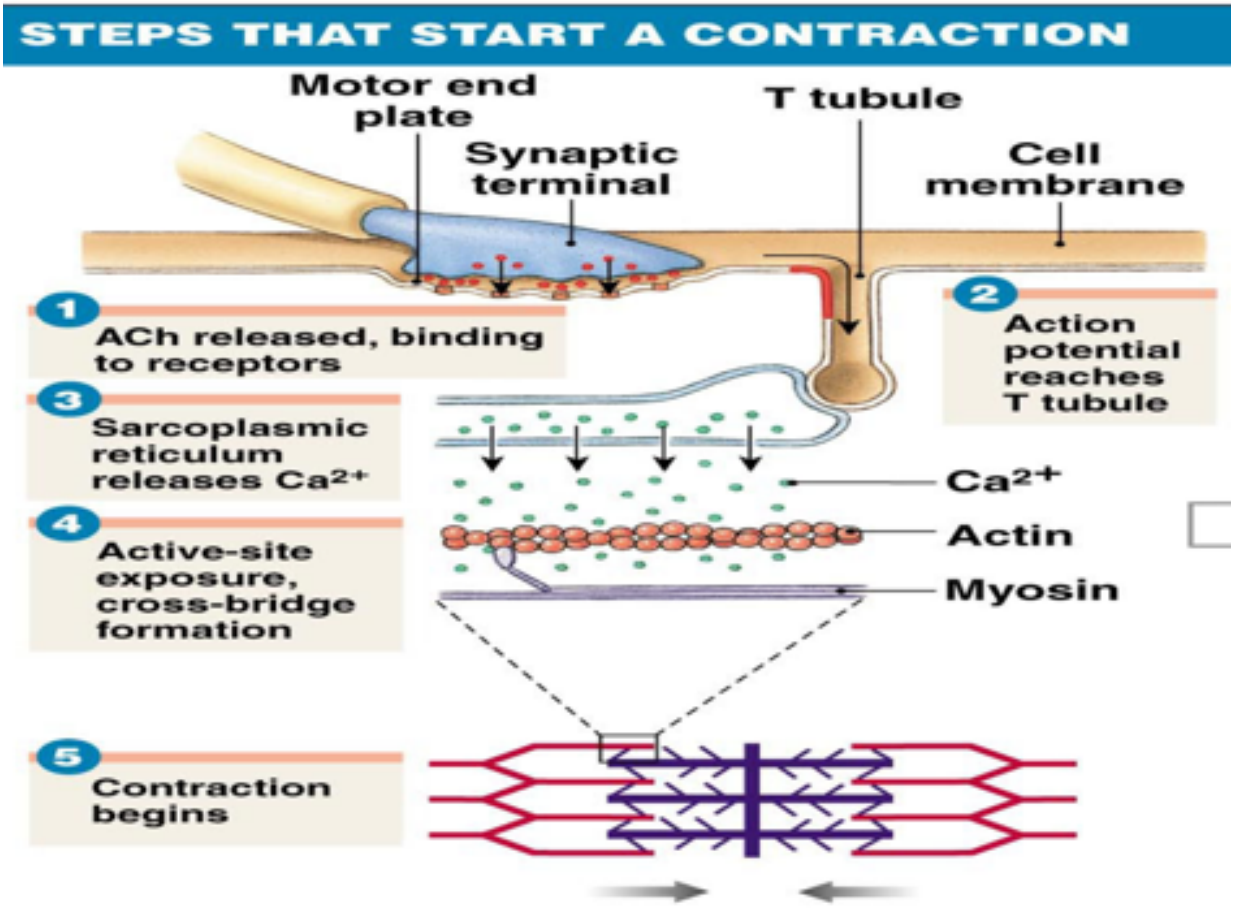
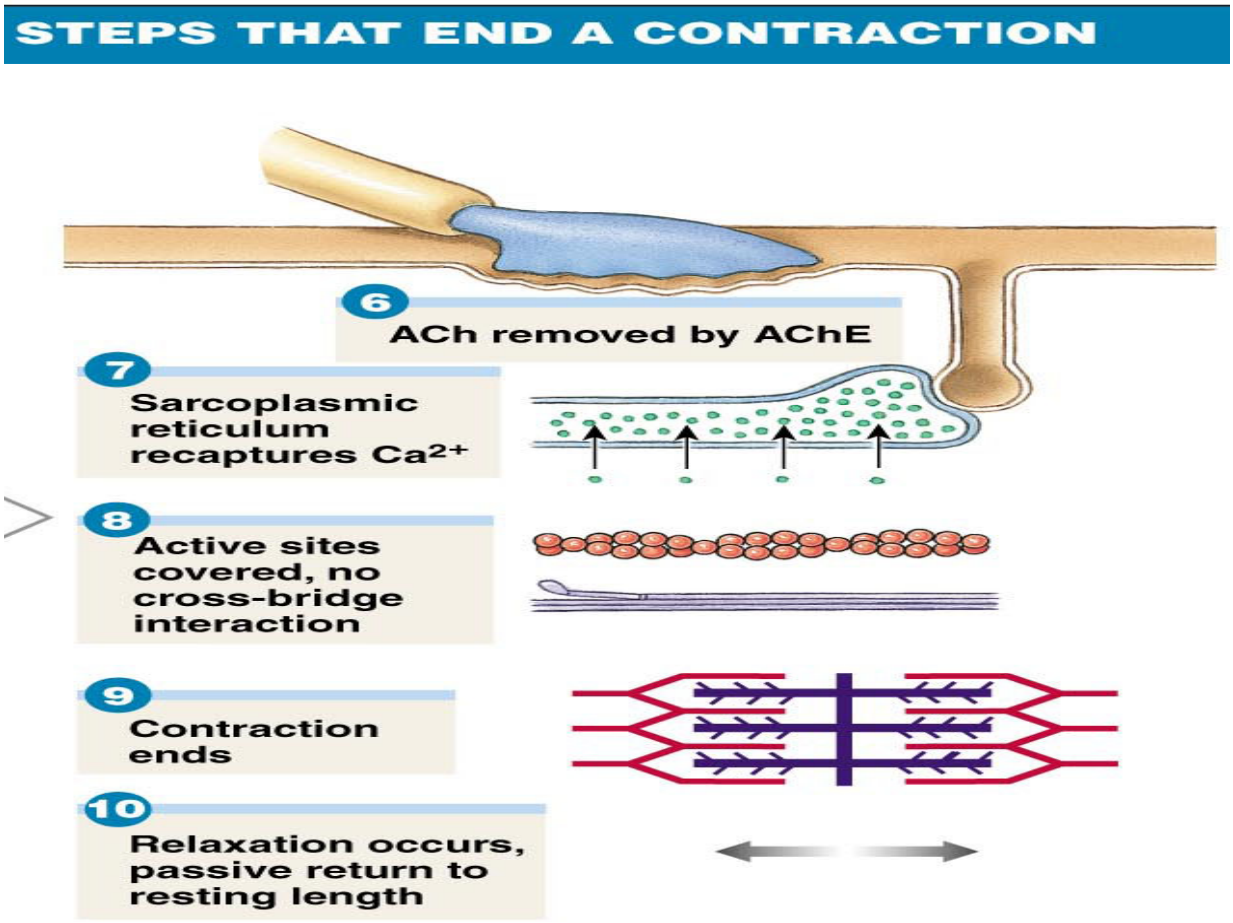


Physiology of Skeletal Muscle Contraction

- Once an action potential (AP) is generated at the motor end plate it will spread like an electrical current along the sarcolemma of the muscle fiber
- The AP will also spread into the T-tubules, exciting the terminal cisternae of the sarcoplasmic reticula
- This will cause Calcium (Ca^{+2}) gates in the SR to open, allowing Ca^{+2} to diffuse into the sarcoplasm
- Calcium will bind to troponin (on the thin myofilament), causing it to change its shape. This then pulls tropomyosin away from the active sites (myosin binding sites) of actin molecules.
- The exposure of the active sites allow myosin to bind to actin, and cause the sliding of the filaments



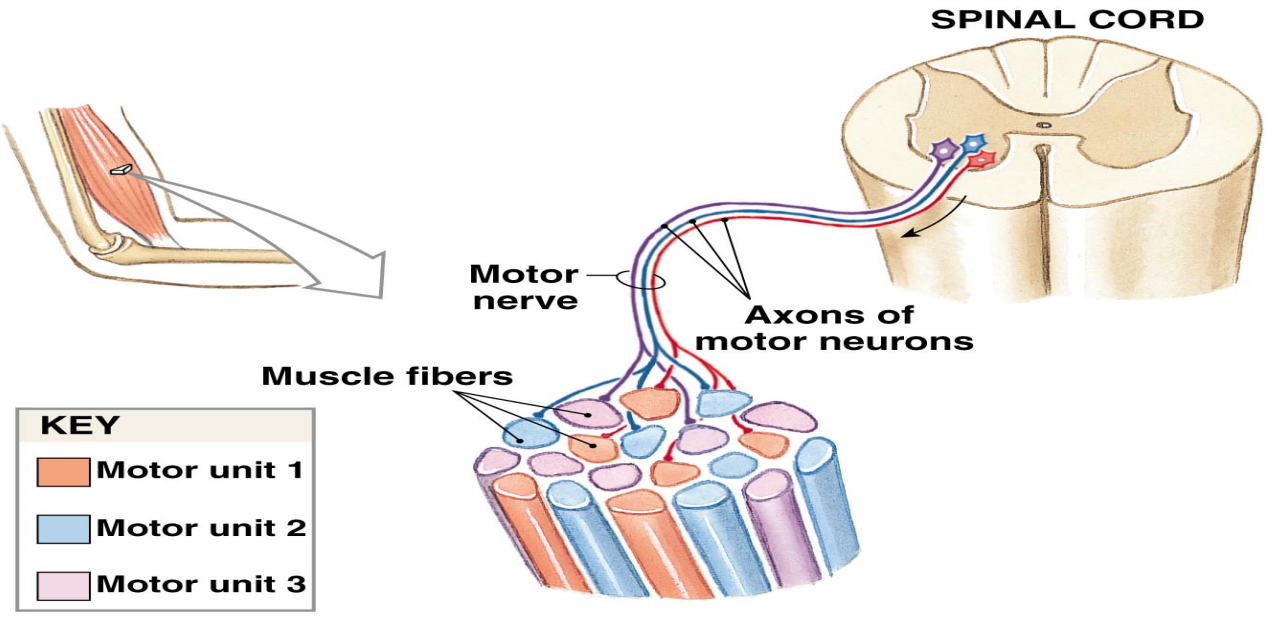
Physiology of Skeletal Muscle Contraction

- If there are no longer APs generated on the motor neuron, no more ACh will be released
- AChE will remove ACh from the motor end plate, and AP transmission on the muscle fiber will end
- Ca^{+2} gates in the SR will close & Ca^{+2} will be actively transported back into the SR
- With Ca^{+2} removed from the sarcoplasm (& from troponin), tropomyosin will re-cover the active sites of actin
- No more cross-bridge interactions can form
- Thin myofilaments slide back to their resting state
- Skeletal muscle fibers shorten as thick filaments interact with thin filaments ("cross bridge") and sliding occurs ("power stroke").
- The trigger for contraction is the calcium ions released by the SR when the muscle fiber is stimulated by its motor neuron.
- Contraction is an active process; relaxation and the return to resting length is entirely passive.

These physiological processes describe what happen at the cellular level – how skeletal muscle *fibers* contract.

But what about at the organ level? How do skeletal *muscles* (like your biceps brachii) contract to create useful movement?

- Skeletal muscles are made up of thousands of muscle fibers
- A single motor neuron may directly control a few fibers within a muscle, or hundreds to thousands of muscle fibers
- All of the muscle fibers controlled by a single motor neuron constitute a *motor unit*
- The size of the motor unit determines how fine the control of movement can be
    - small motor units → precise control (e.g. eye muscles
    - large motor units →gross control (e.g. leg muscles)



Recruitment

- is the ability to activate more motor units as more force (tension) needs to be generated

Hypertrophy

- "stressing" a muscle (i.e. exercise) causes more myofilaments/myofibrils to be produced within muscle fibers; allows for more "cross bridges" resulting in more force (strength) as well as larger size
- There are always some motor units active, even when at rest. This creates a resting tension known as *muscle tone,* which helps stabilize bones & joints, & prevents atrophy