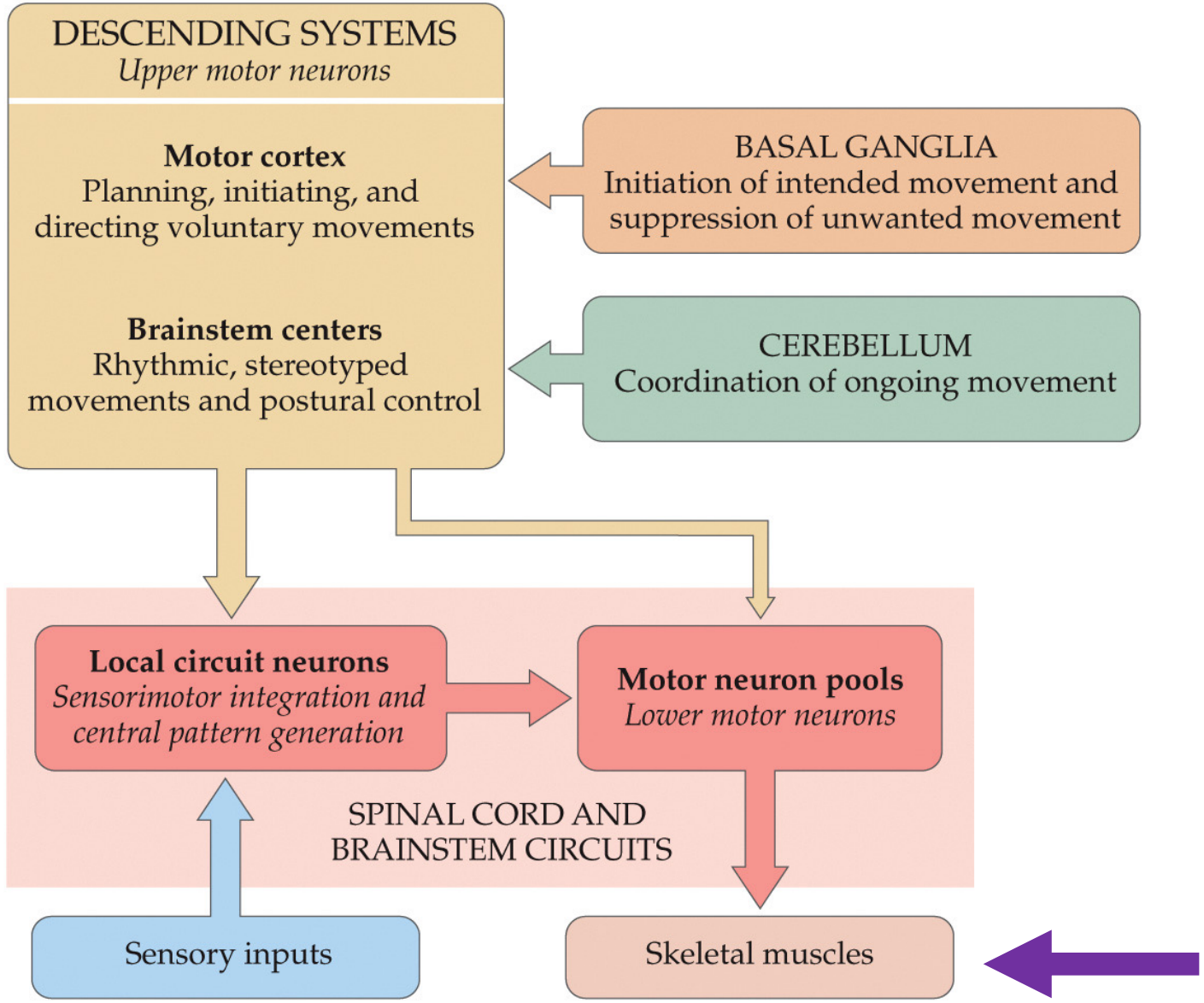
BMD ENG 301
Quantitative Systems Physiology
(Nervous System)

Muscle
2022_v2

Prof Malcolm MacIver



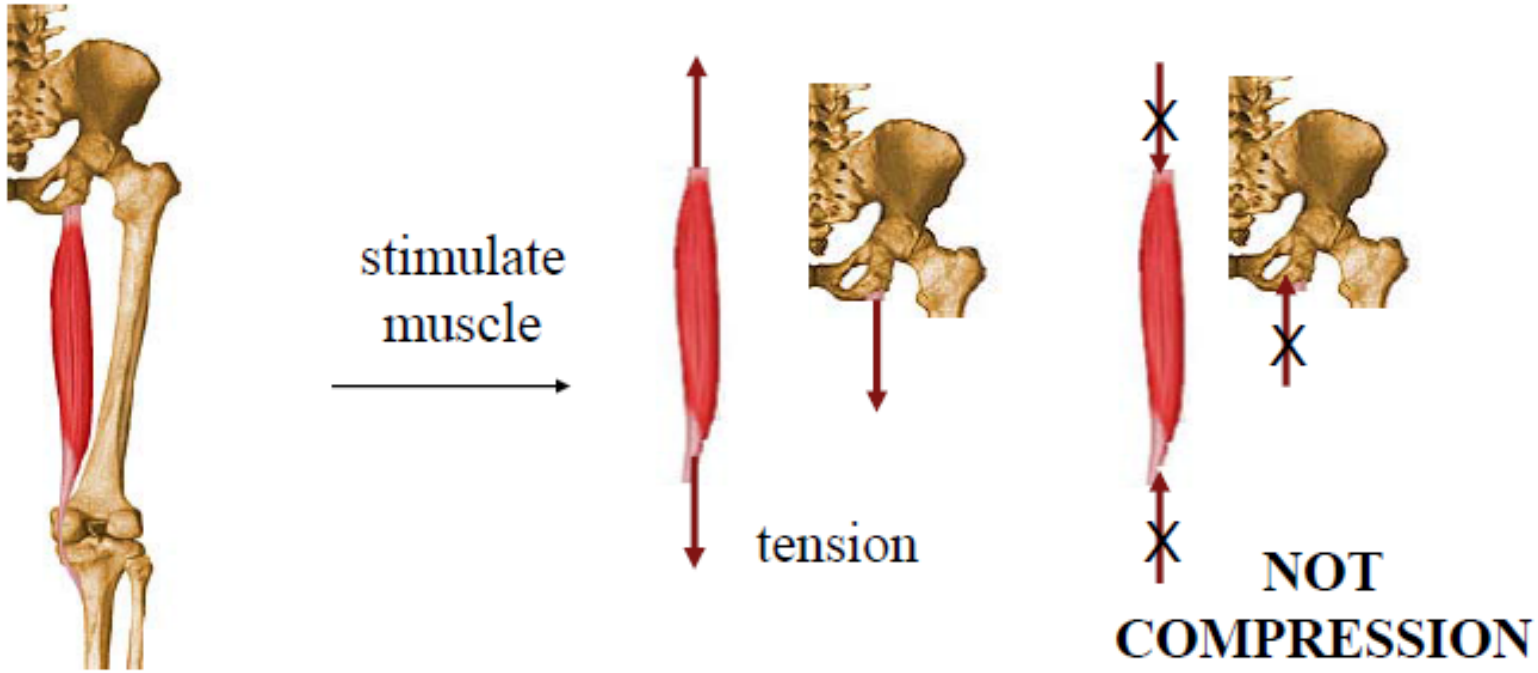
NEUROSCIENCE 6e, Figure 16.1

Agenda

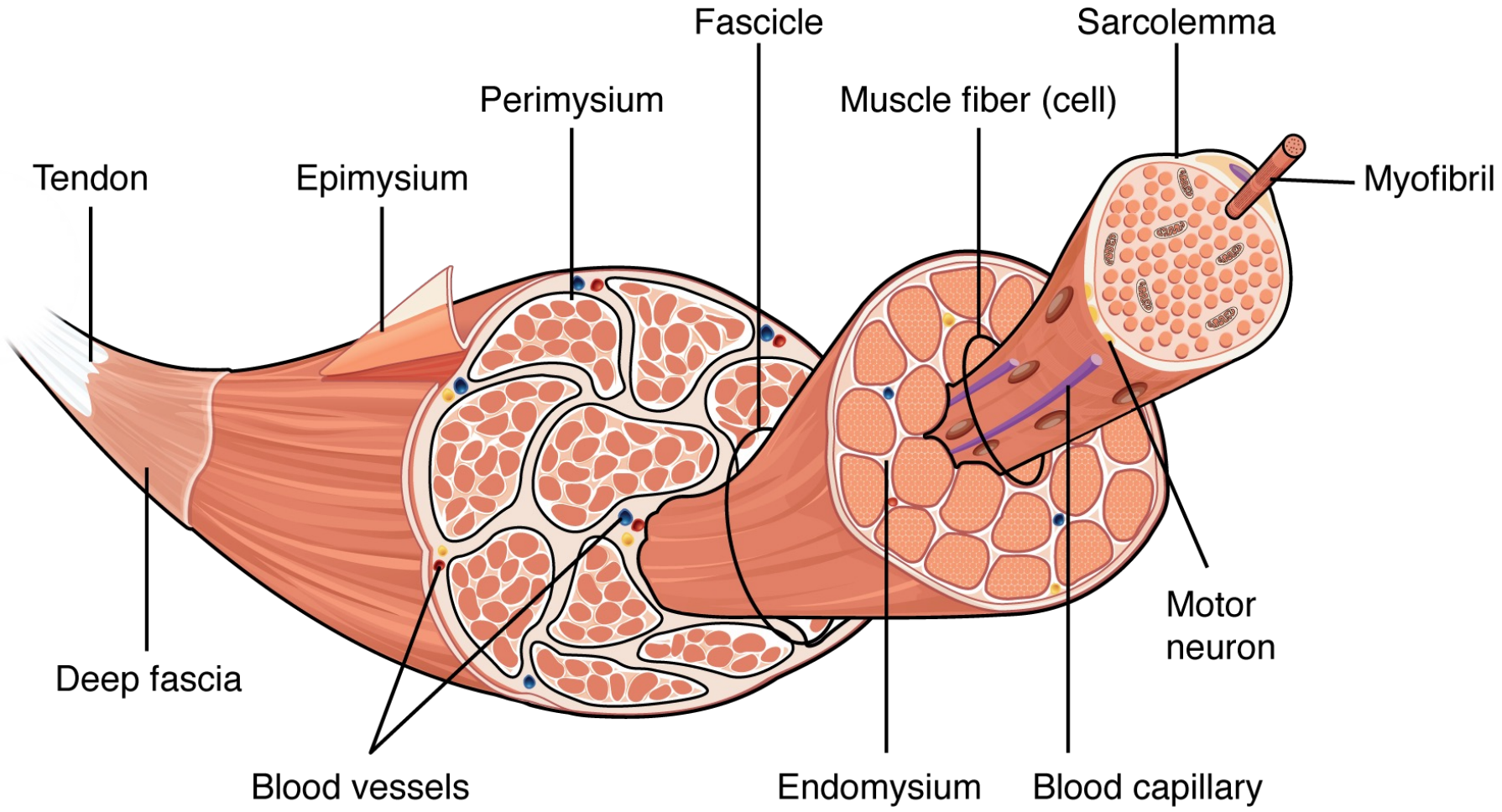
- Muscle structure
- Neuromuscular junction
- Excitation-contraction coupling
- Sliding Filament Theory
- Properties of skeletal muscle
- Muscle signals and acquisition

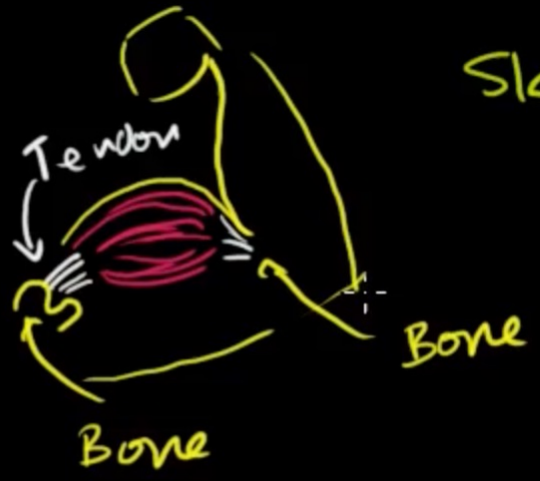
Muscle Structure and the Neuromuscular Junction

Contractility: Muscles are the ONLY tissue capable of actively generating tension (force) when stimulated



Muscle Structure and the Neuromuscular Junction





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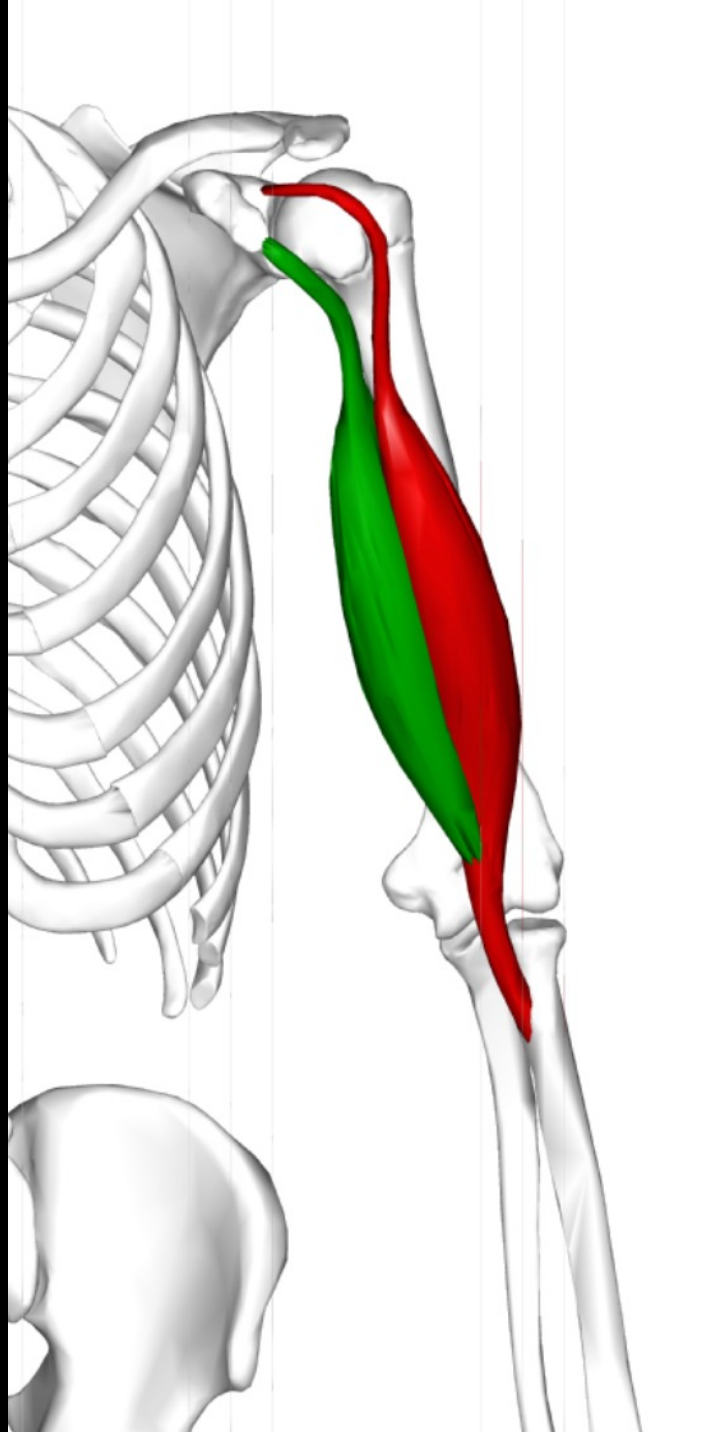
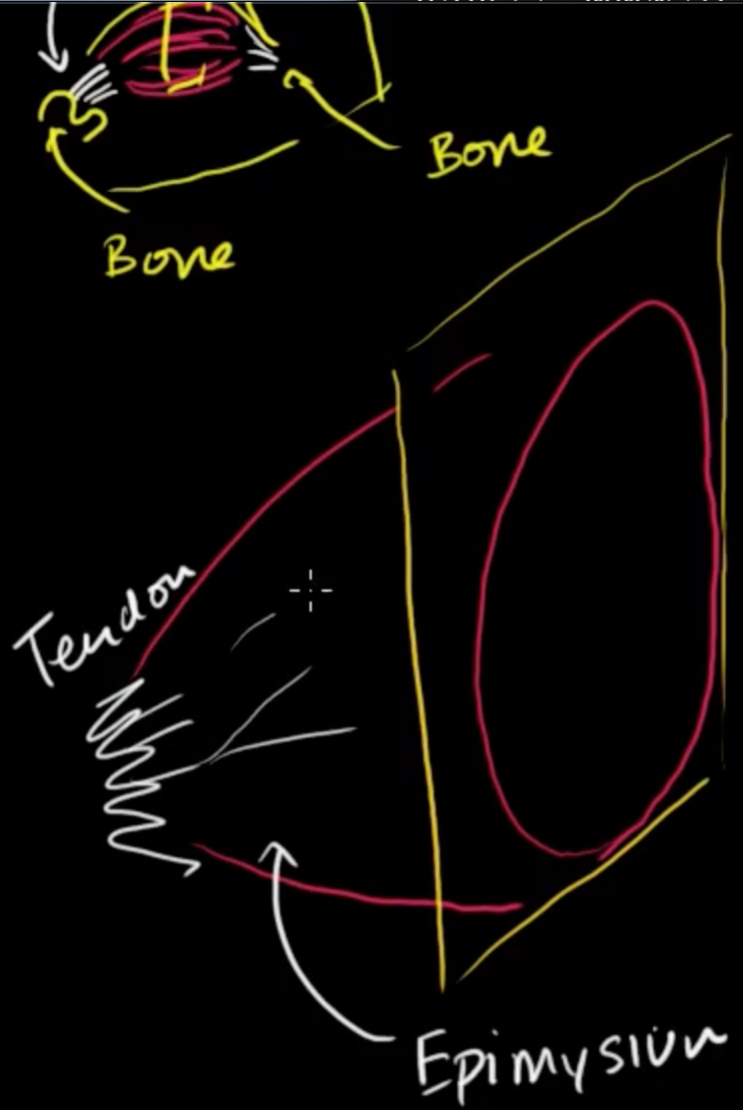
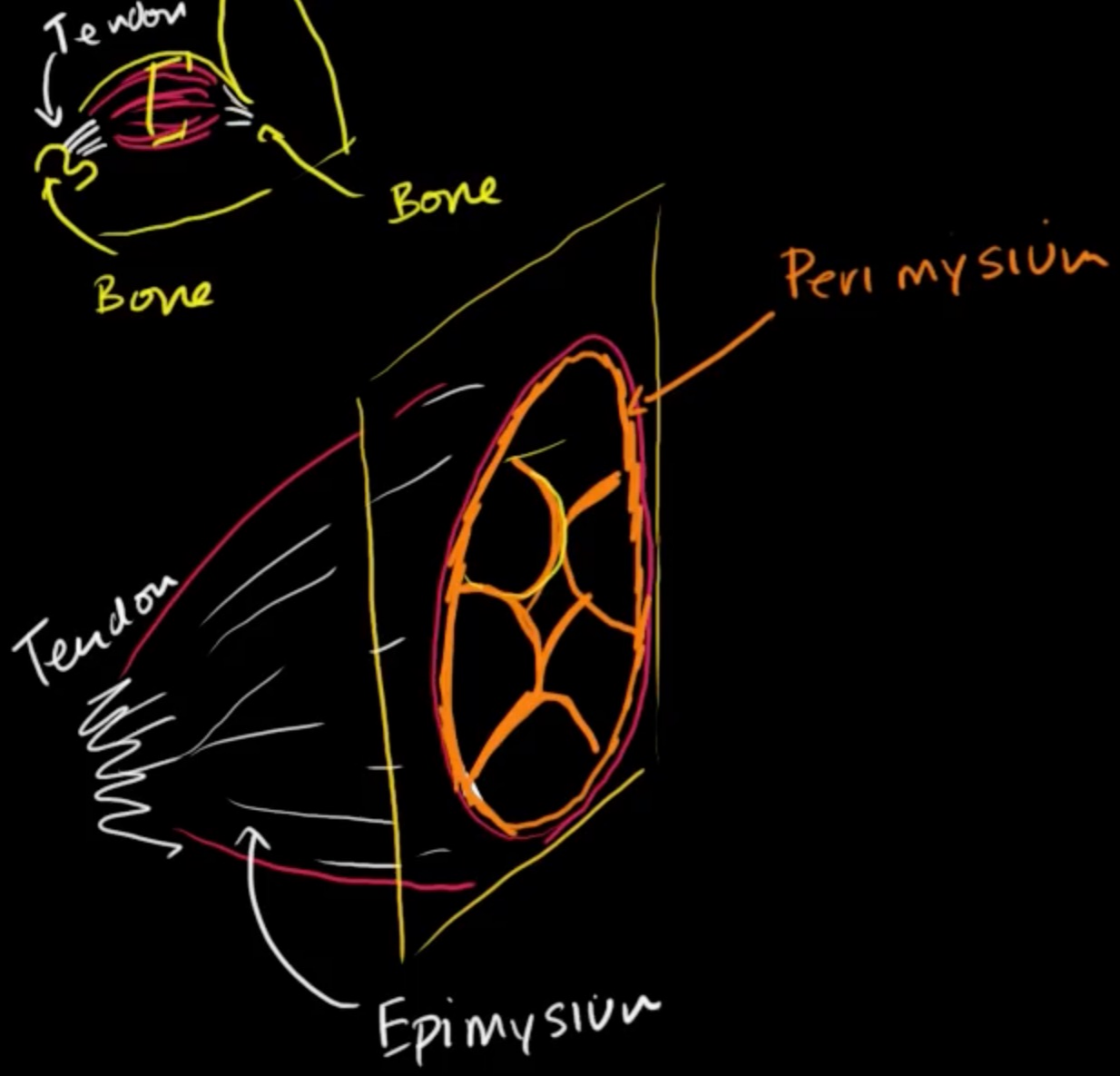
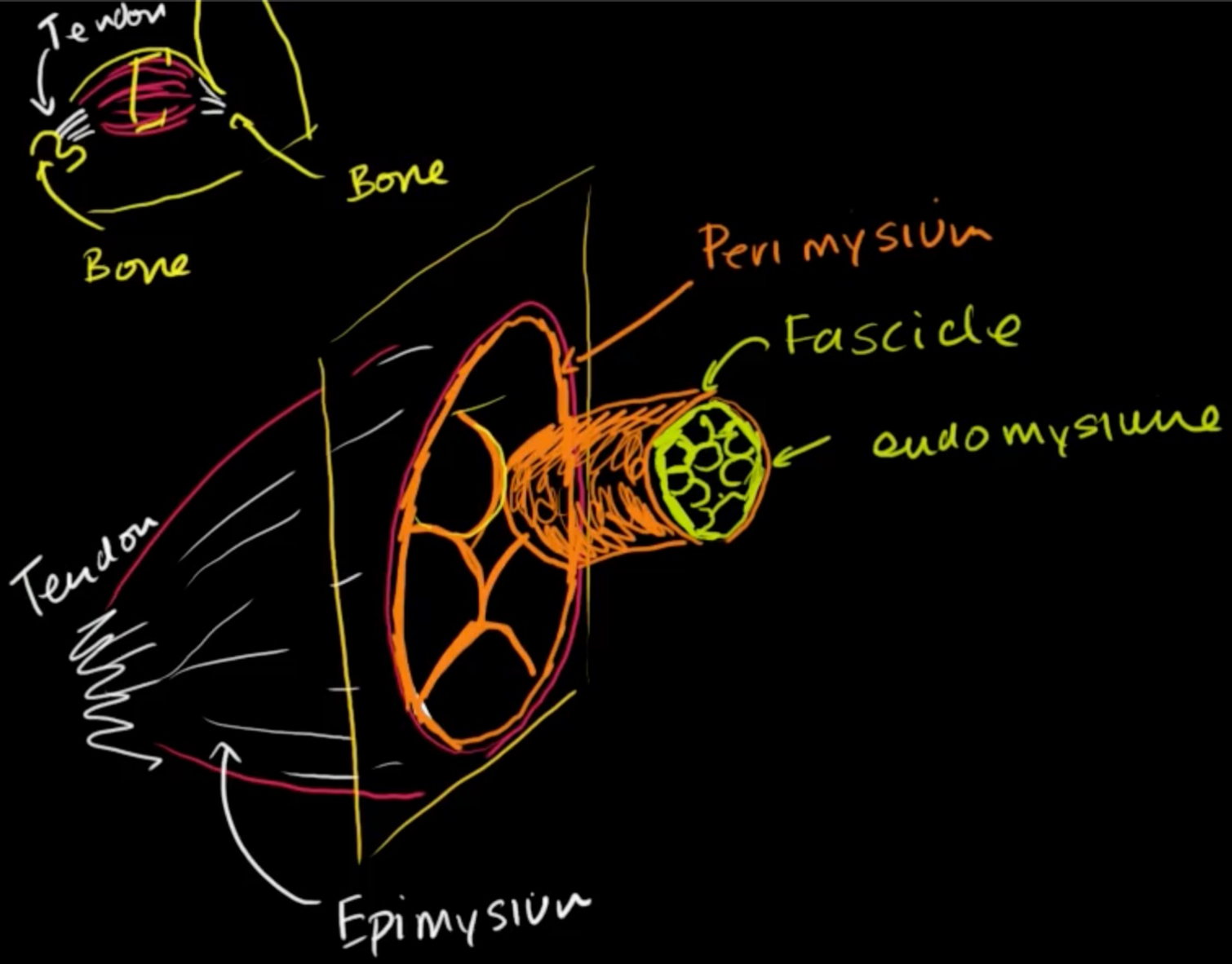
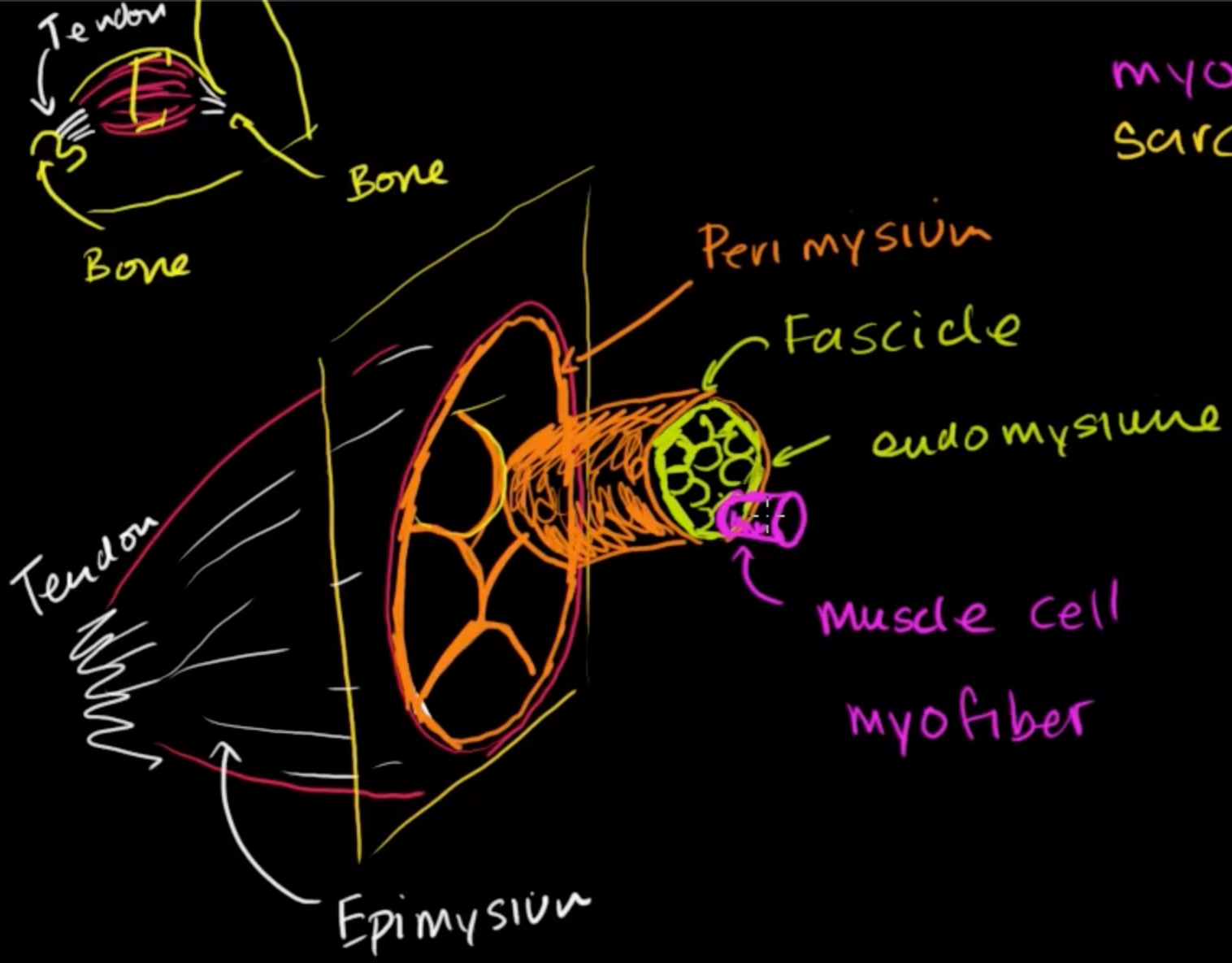


Skeletal Muscle

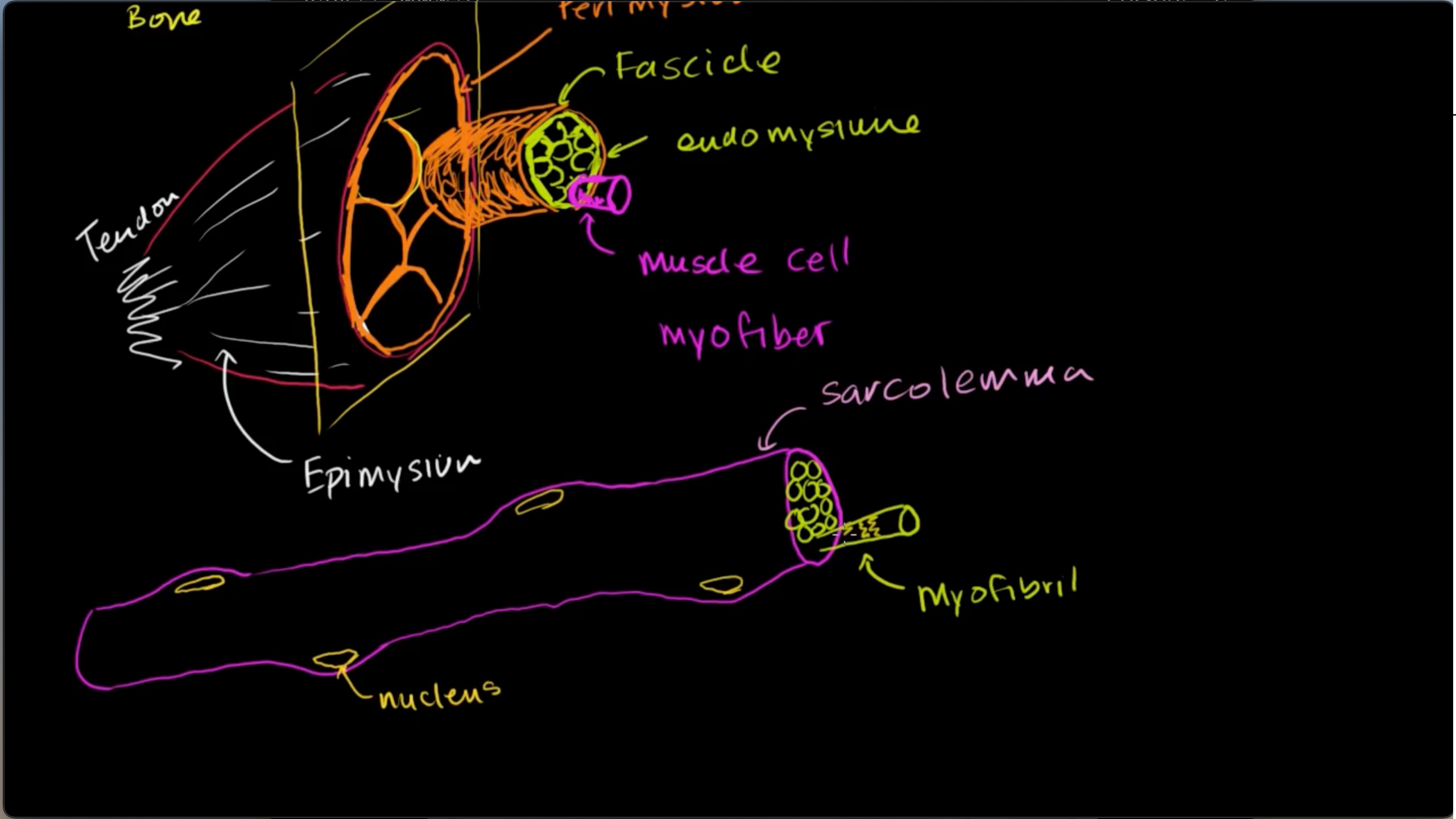

Bone
Bone
Tendon
Epimysium

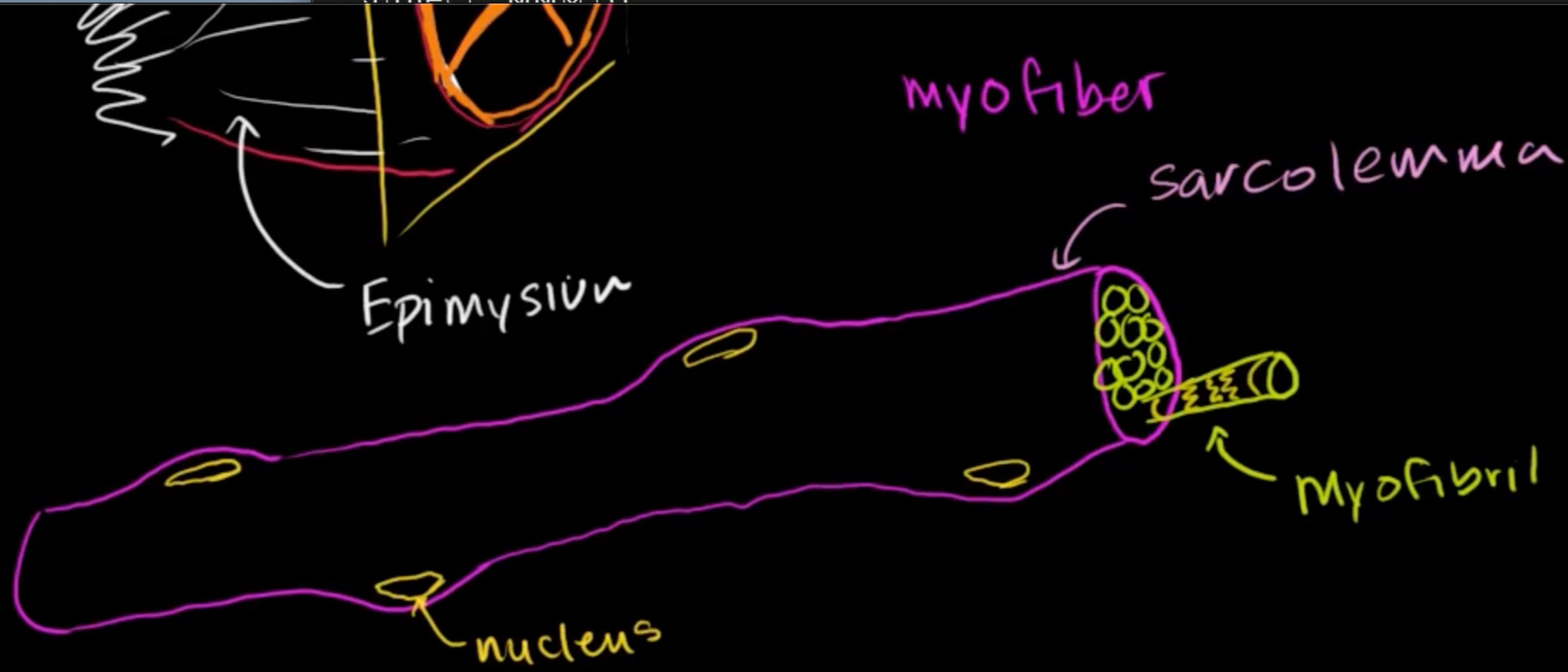

Tendon
Bone
Bone
Perimysium
Tendon
Epimysium

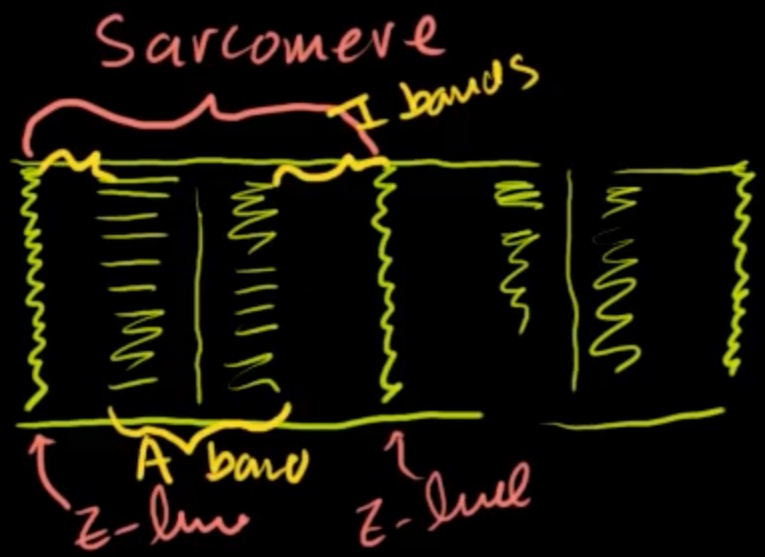

Tendon
Bone
Bone
Perimysium
Fascicle
endomysium
Tendon
Epimysium

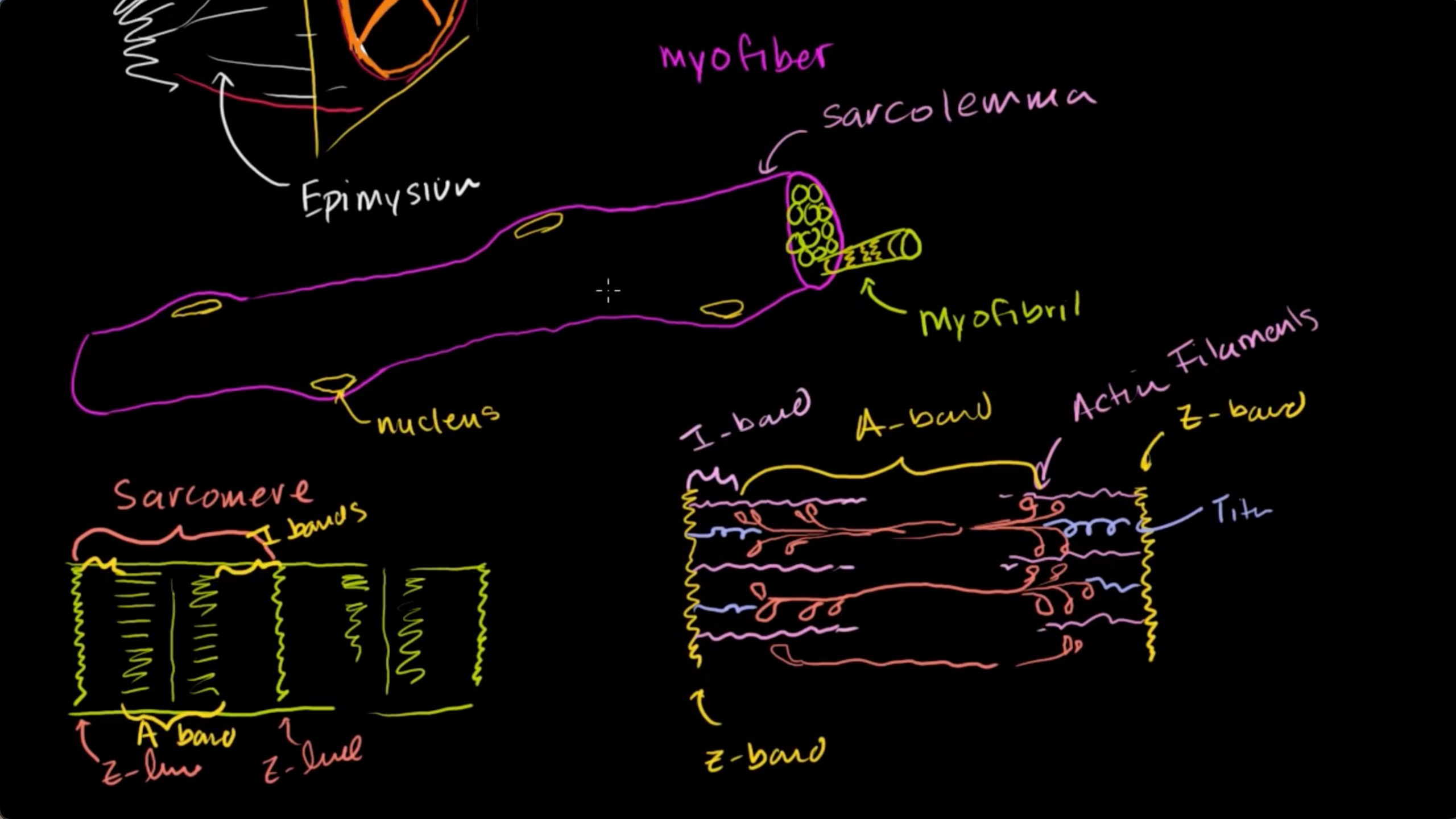


myo - muscle
sarco - flesh


Bone
Fascicle
endomysium
Tendon
Muscle cell
myofiber
sarcolemma
Epimysium
Myofibril
nucleus


myofiber
sarcolemma
Epimysium
Myofibril
nucleus


Sarcomere
I bands
A band
Z-line
Z-line


Epimysium
myofiber
sarcolemma
Myofibril
nucleus
Sarcomere
I bands
A band
Z-line
Z-line
I-band
A-band
Actin Filaments
Z-band
Titin
Z-band

Muscle Structure and the Neuromuscular Junction

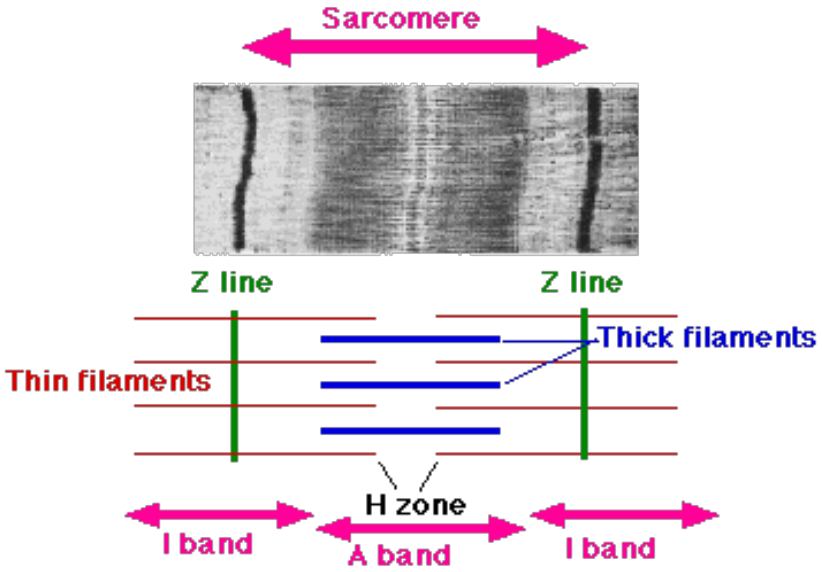
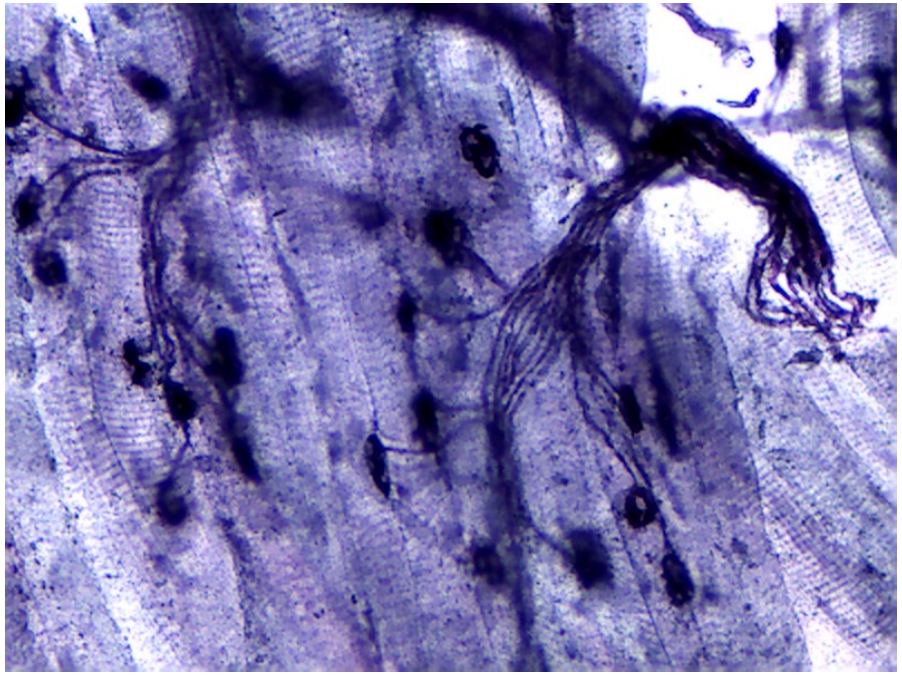
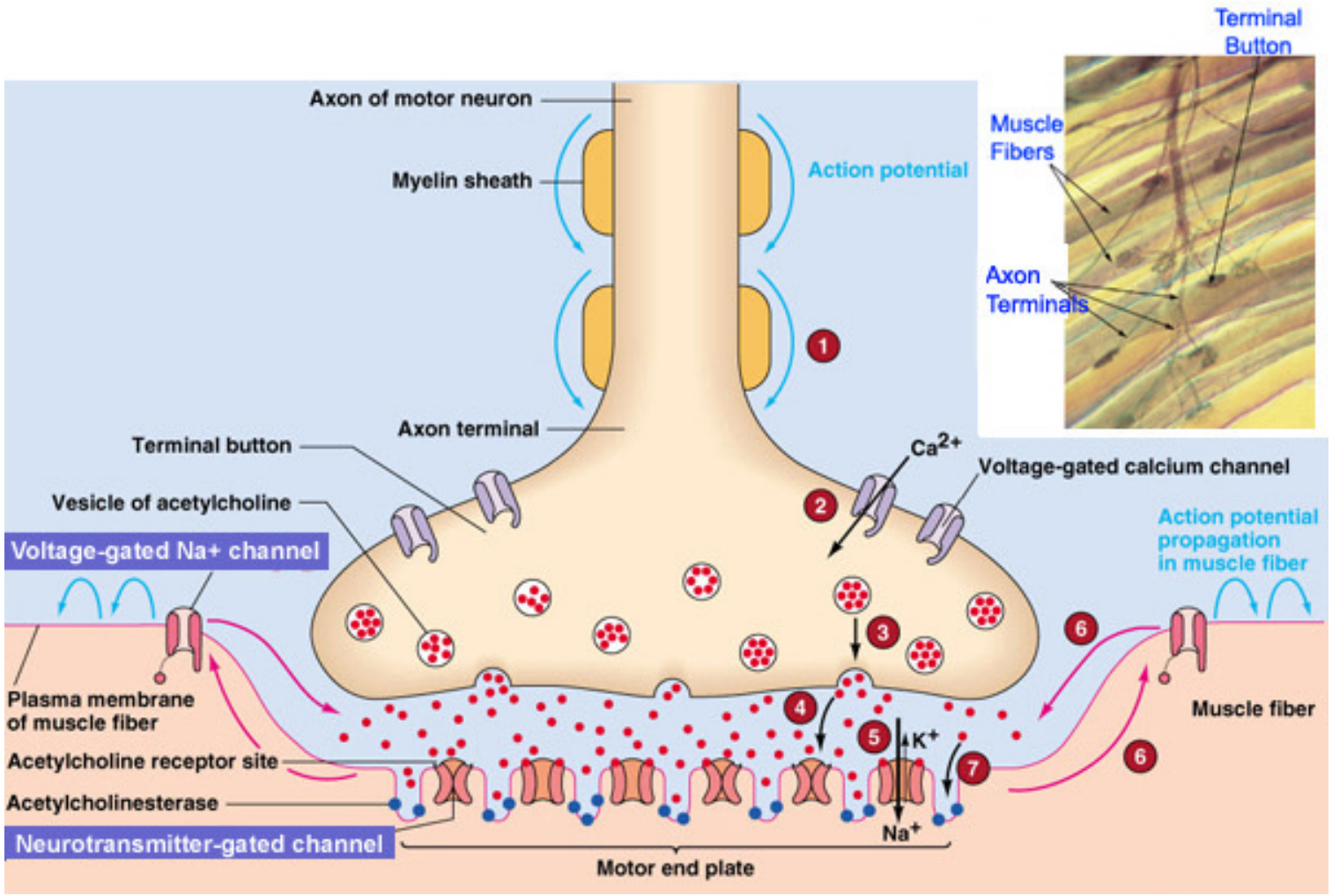


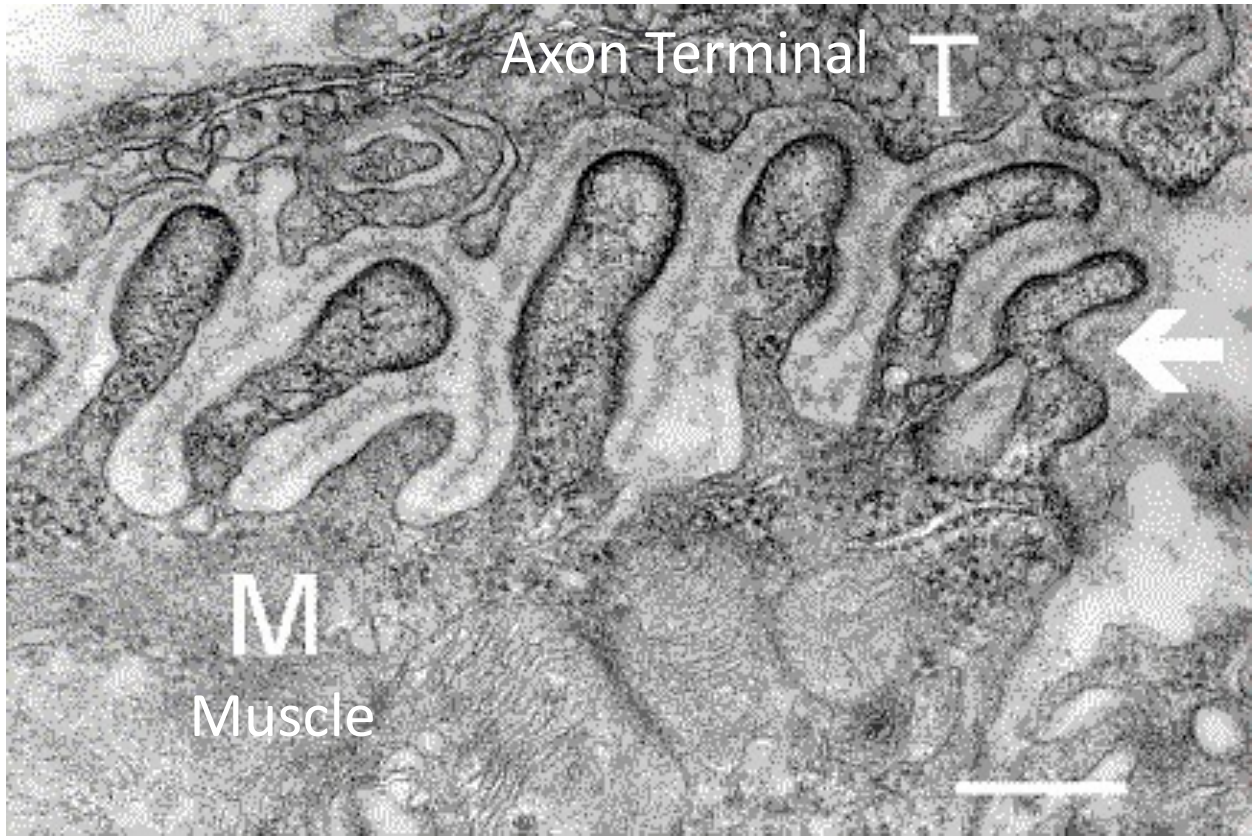
Figure 8–22. Electron micrograph of a transverse section of insect flight muscle showing the regular hexagonal array of thick and thin filaments in the A band of a myofibril. × 350,000. (After Hanson and Huxley, Scientific American, 1960.)



The Neuromuscular Junction



The Neuromuscular Junction



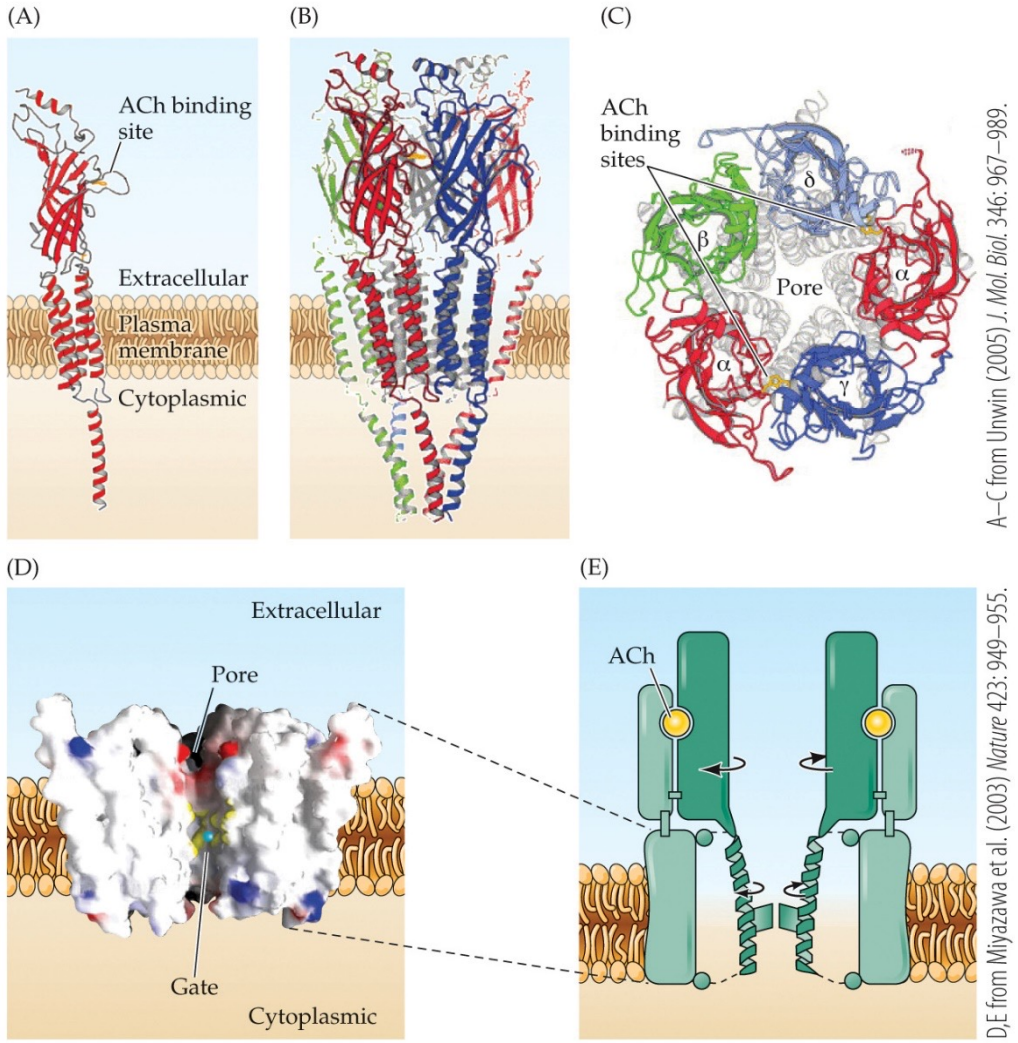
Increased surface area → signal amplification between the neuron and muscle

Acetylcholine Receptors

Acetylcholine is the primary neurotransmitter for motor neuron-muscle communication

Nicotinic AChR:

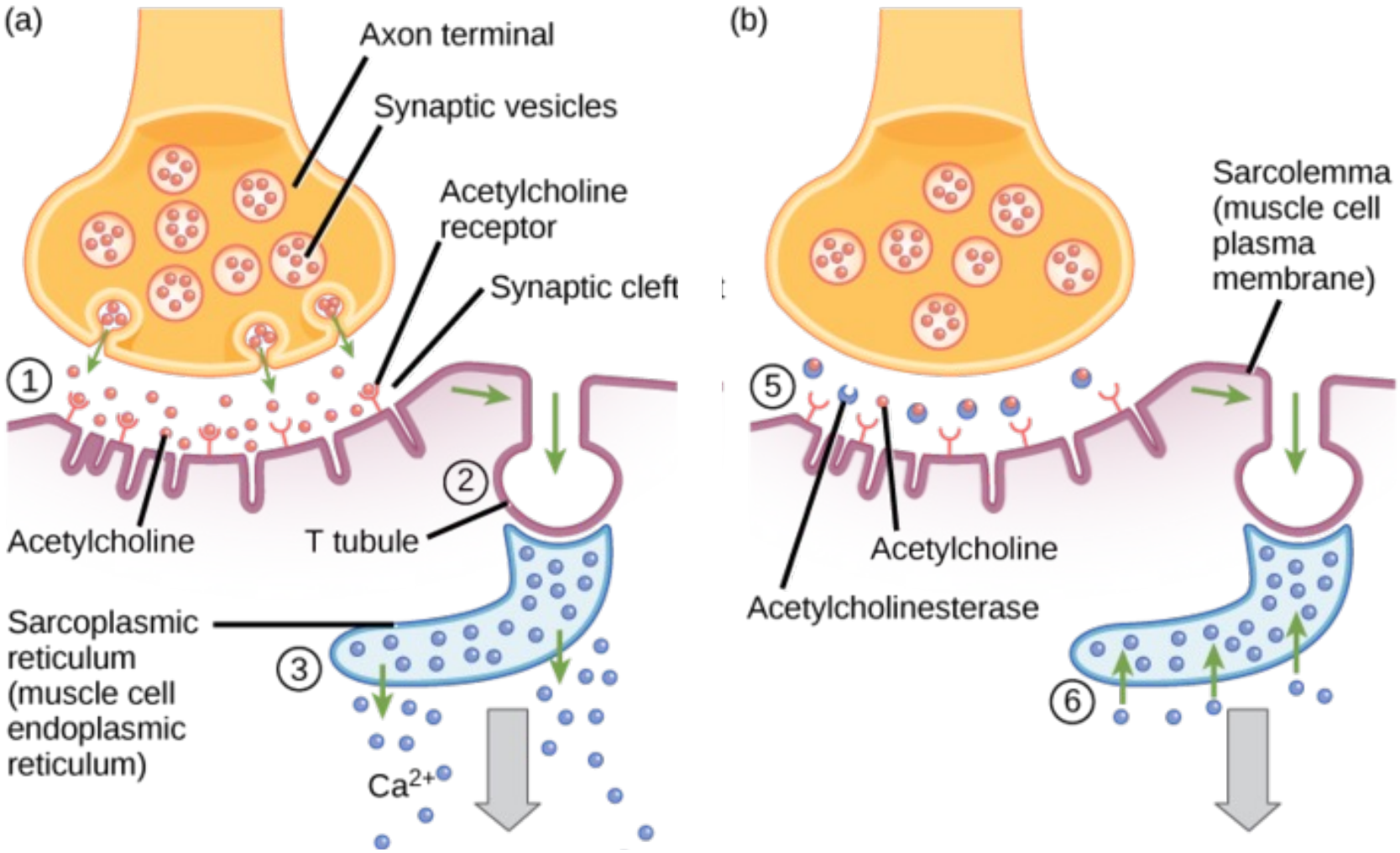
- Ligand-gated
- Ionotropic (allow for nonspecific monovalent cation flow)
- Excitatory



A–C from Unwin (2005) *J. Mol. Biol.* 346: 967–989.

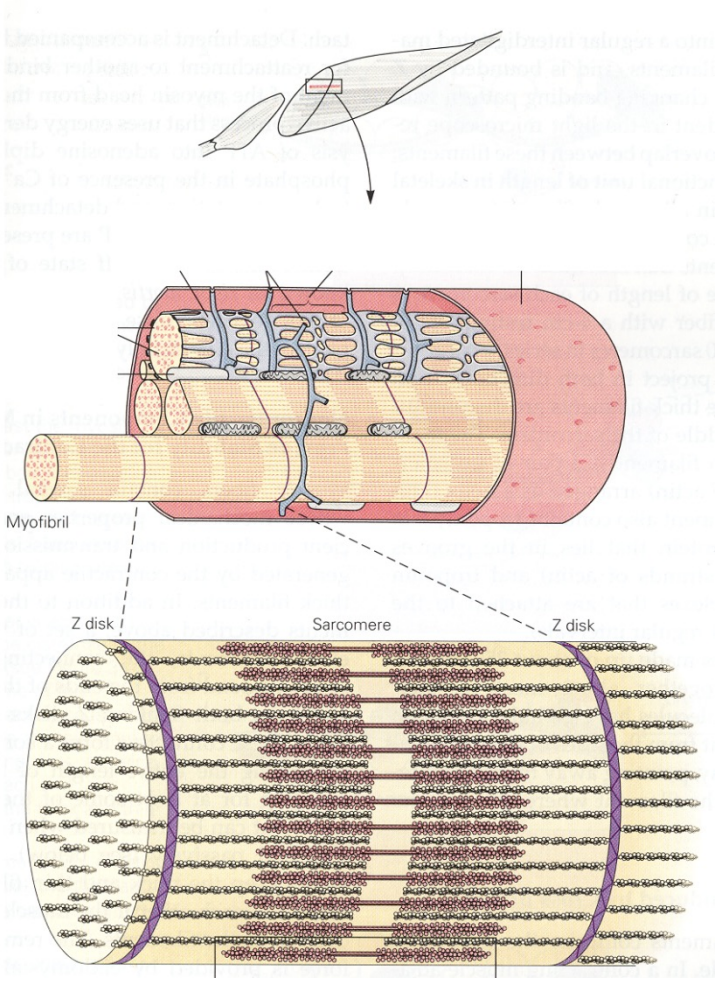
D,E from Miyazawa et al. (2003) *Nature* 423: 949–955.

Excitation of Muscle



Contraction **Relaxation**

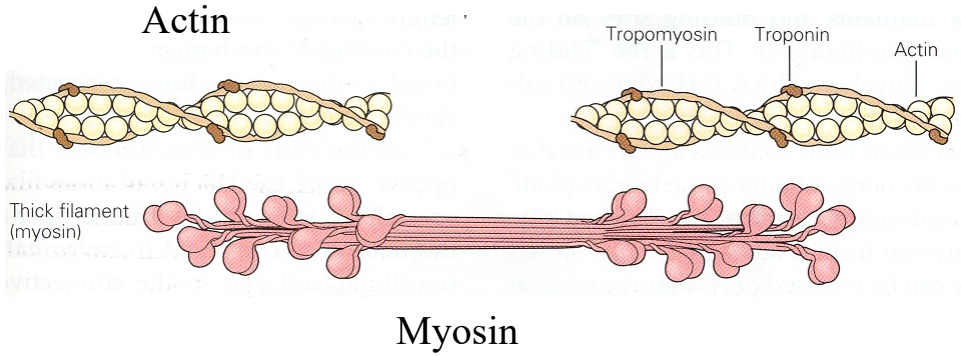
Skeletal Muscle Organization



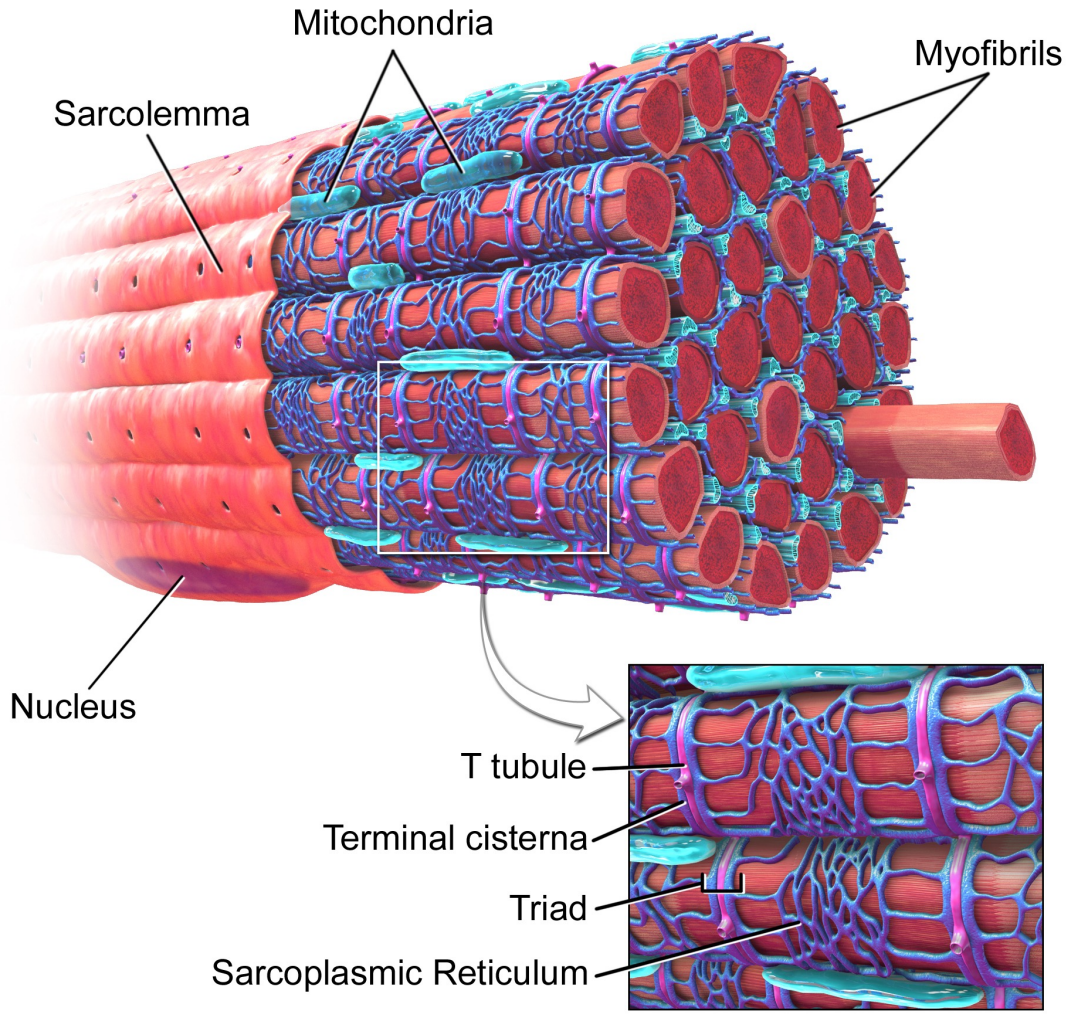
Sarcomere

Mechanism of force production=

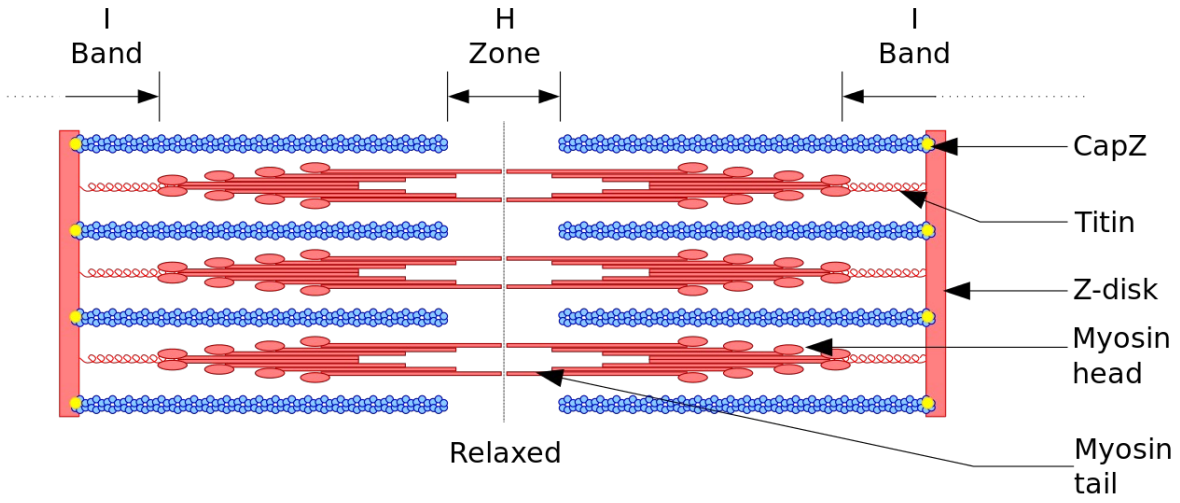
Actin-myosin cross bridges



Myosin


Mitochondria
Myofibrils
Sarcolemma
Nucleus
T tubule
Terminal cisterna
Triad
Sarcoplasmic Reticulum

Sarcomeres and Sliding Filament Theory



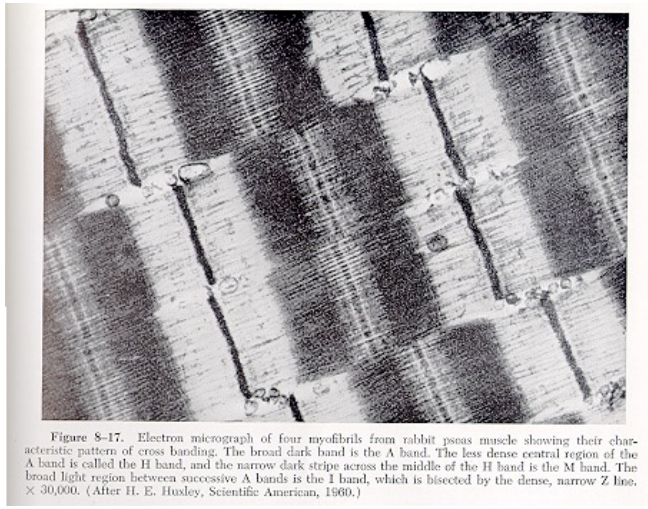
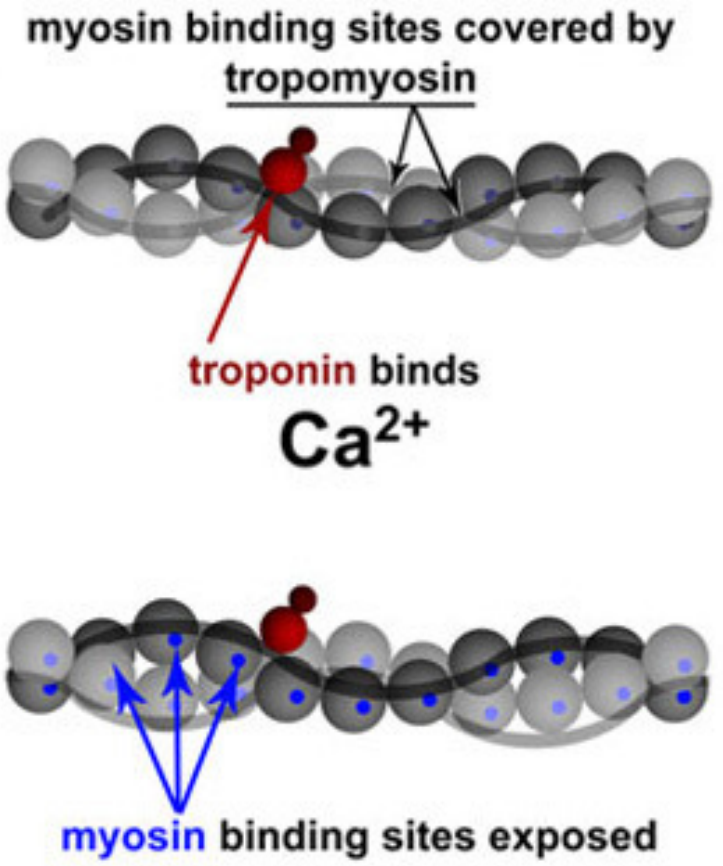


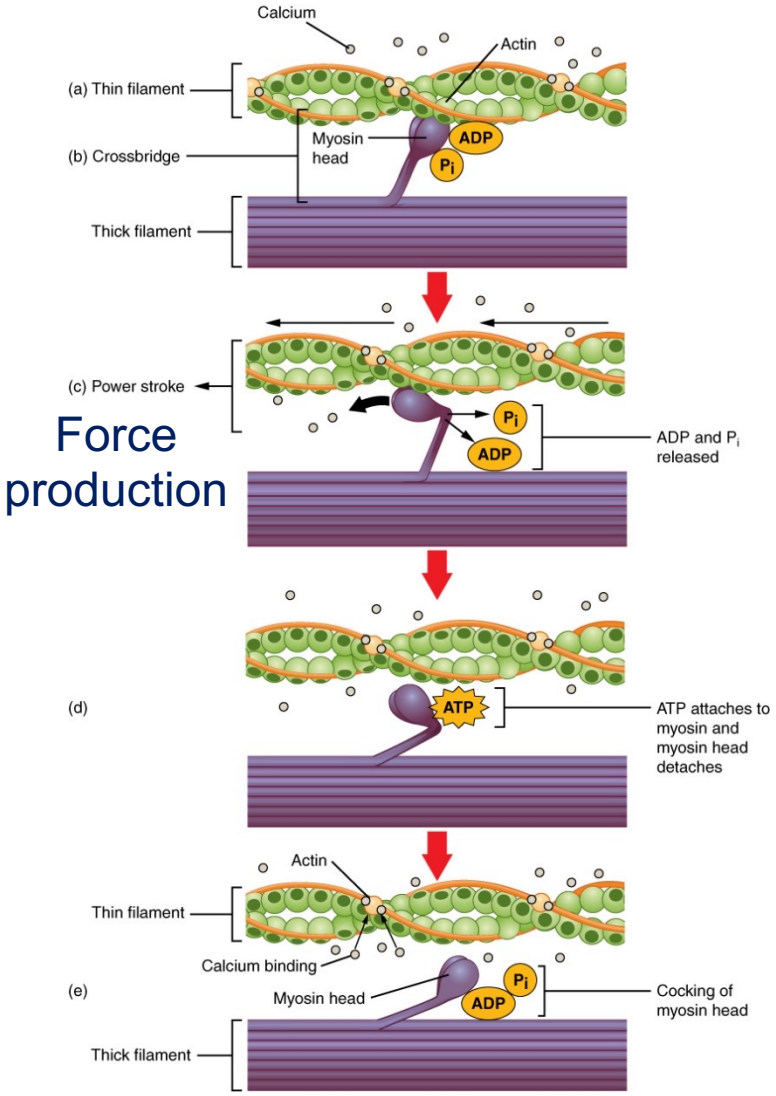
Figure 8–17. Electron micrograph of four myofibrils from rabbit psoas muscle showing their characteristic pattern of cross banding. The broad dark band is the A band. The less dense central region of the A band is called the H band, and the narrow dark stripe across the middle of the H band is the M band. The broad light region between successive A bands is the I band, which is bisected by the dense, narrow Z line. × 30,000. (After H. E. Huxley, Scientific American, 1960.)

Molecular Model of Sliding Filaments

Calcium influx from the sarcoplasmic reticulum



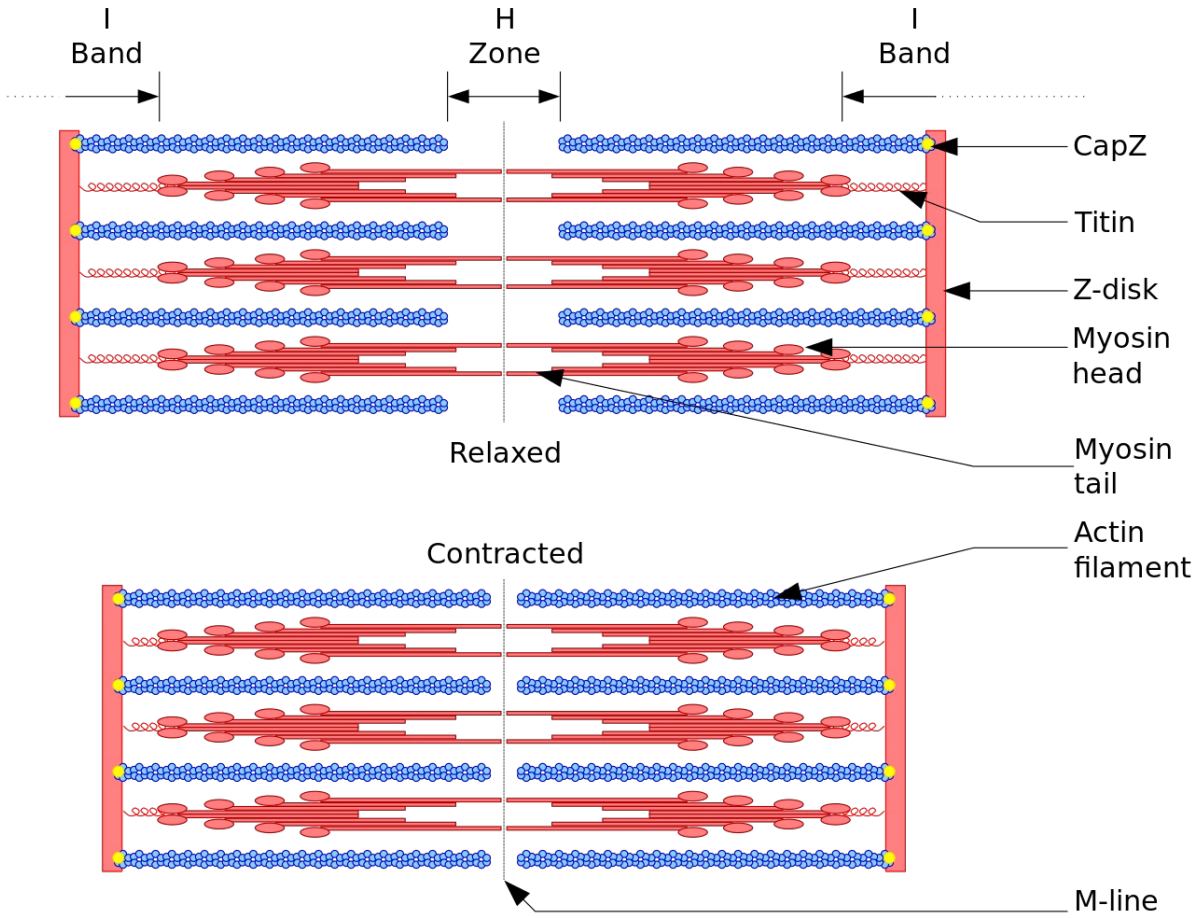
Molecular Model of Sliding Filaments

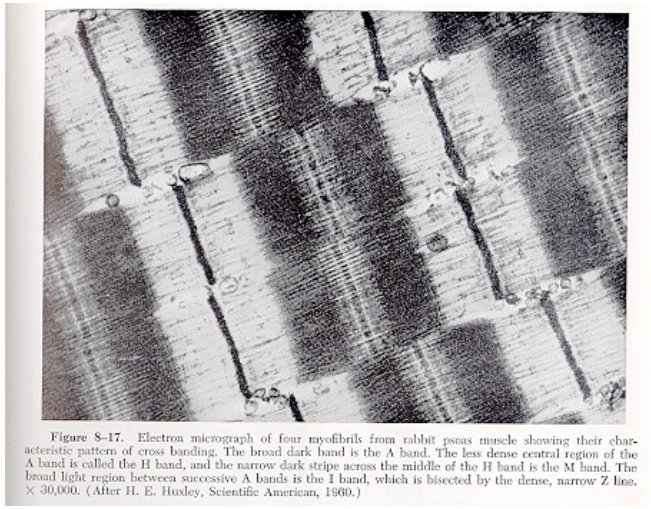


1. Myosin binding sites on actin are exposed as Ca^{2+} binds to troponin
2. The myosin head binds to actin to form a cross-bridge
3. POWER STROKE: the myosin head bends and expels the ADP and P_i
4. ATP binds to the myosin head and causes detachment
5. ATP hydrolyzes into ADP and P_i and returns the myosin to its "cocked" position
6. Cross-bridges can again form and the cycle repeats itself

Number of cross-bridges determines the force produced

Sarcomeres and Sliding Filament Theory





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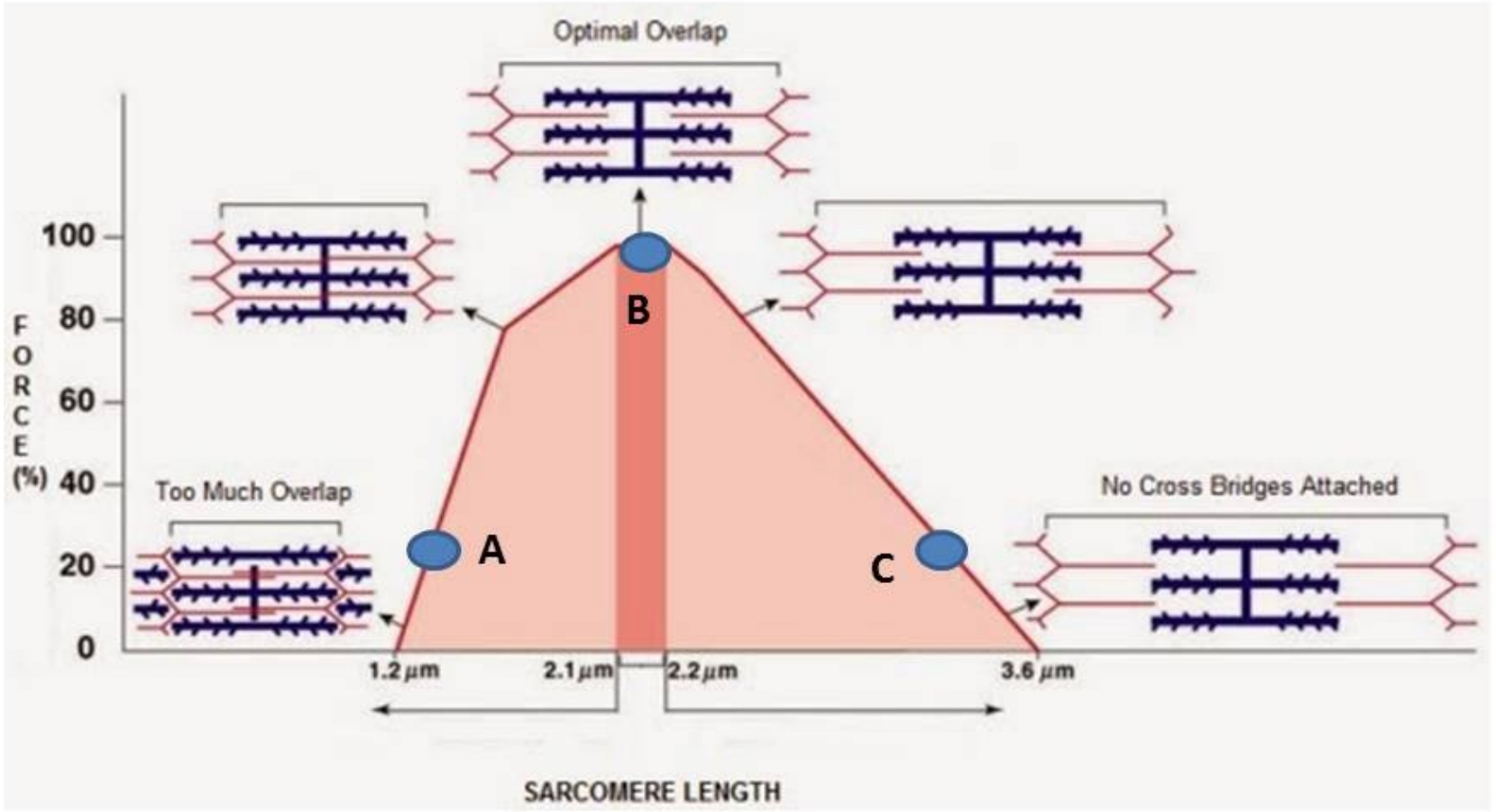
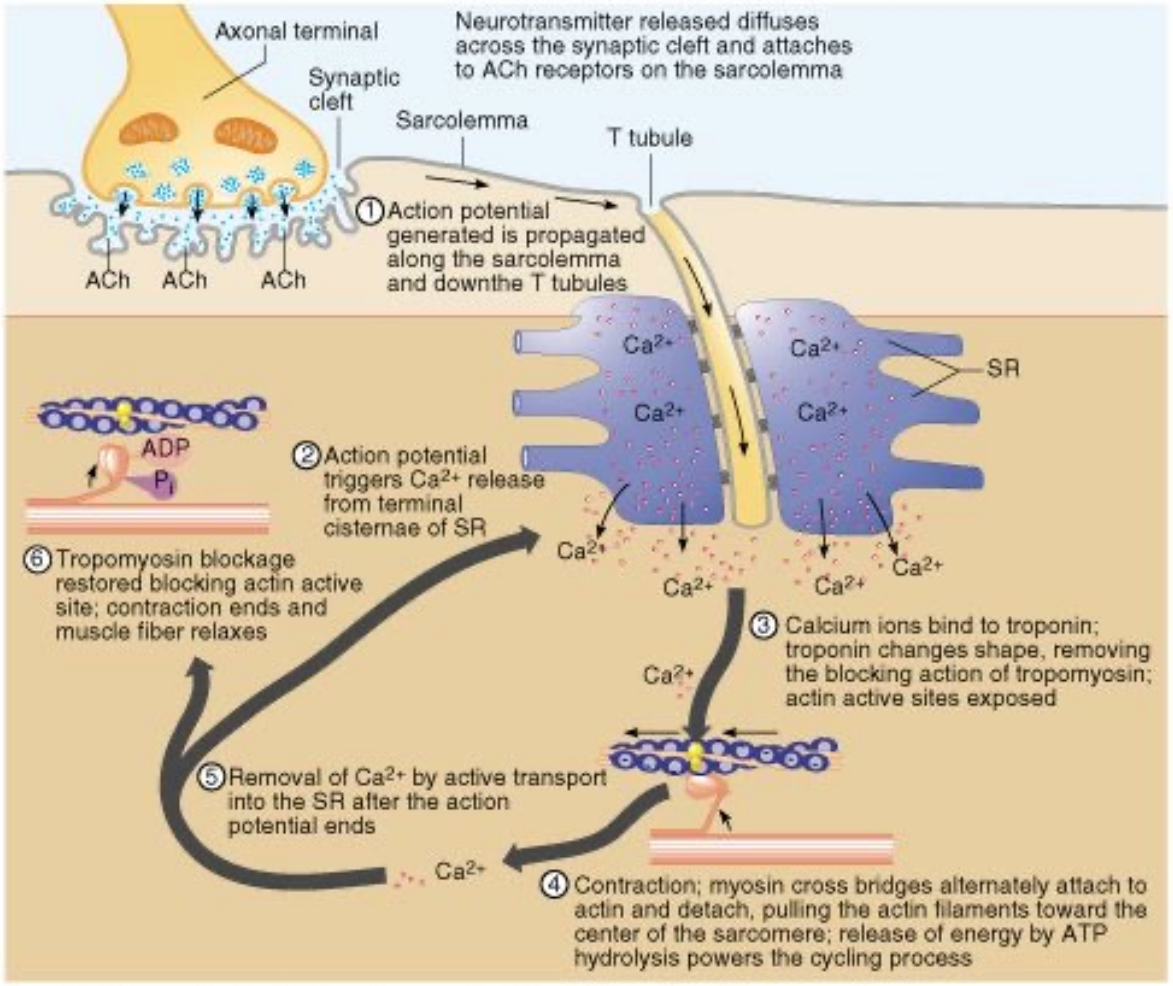
Force Production Based on Sliding Filament Theory

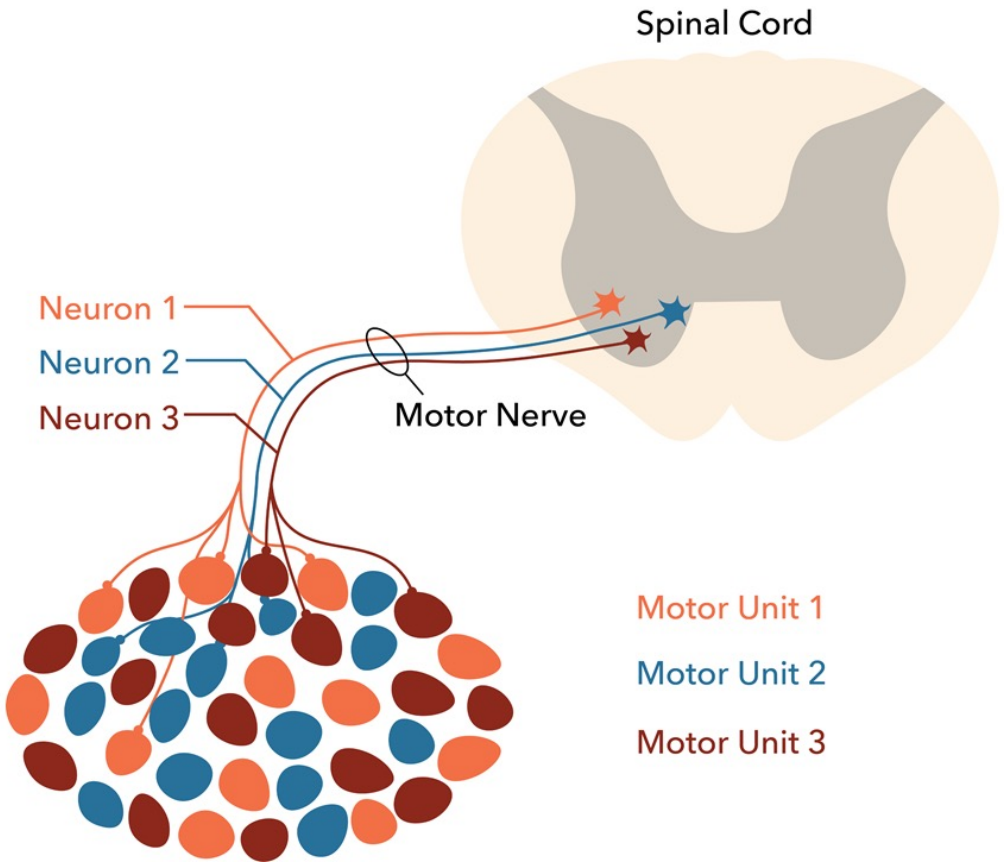
Most important point: number of cross-bridges determines the force!

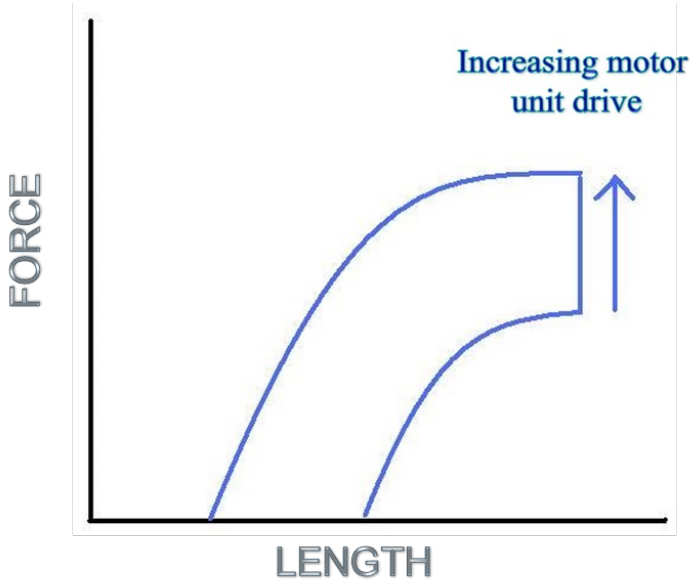


Excitation-Contraction Coupling



Motor Units





Motor unit: a single motor neuron, its axon, and all of the muscle fibers it innervates

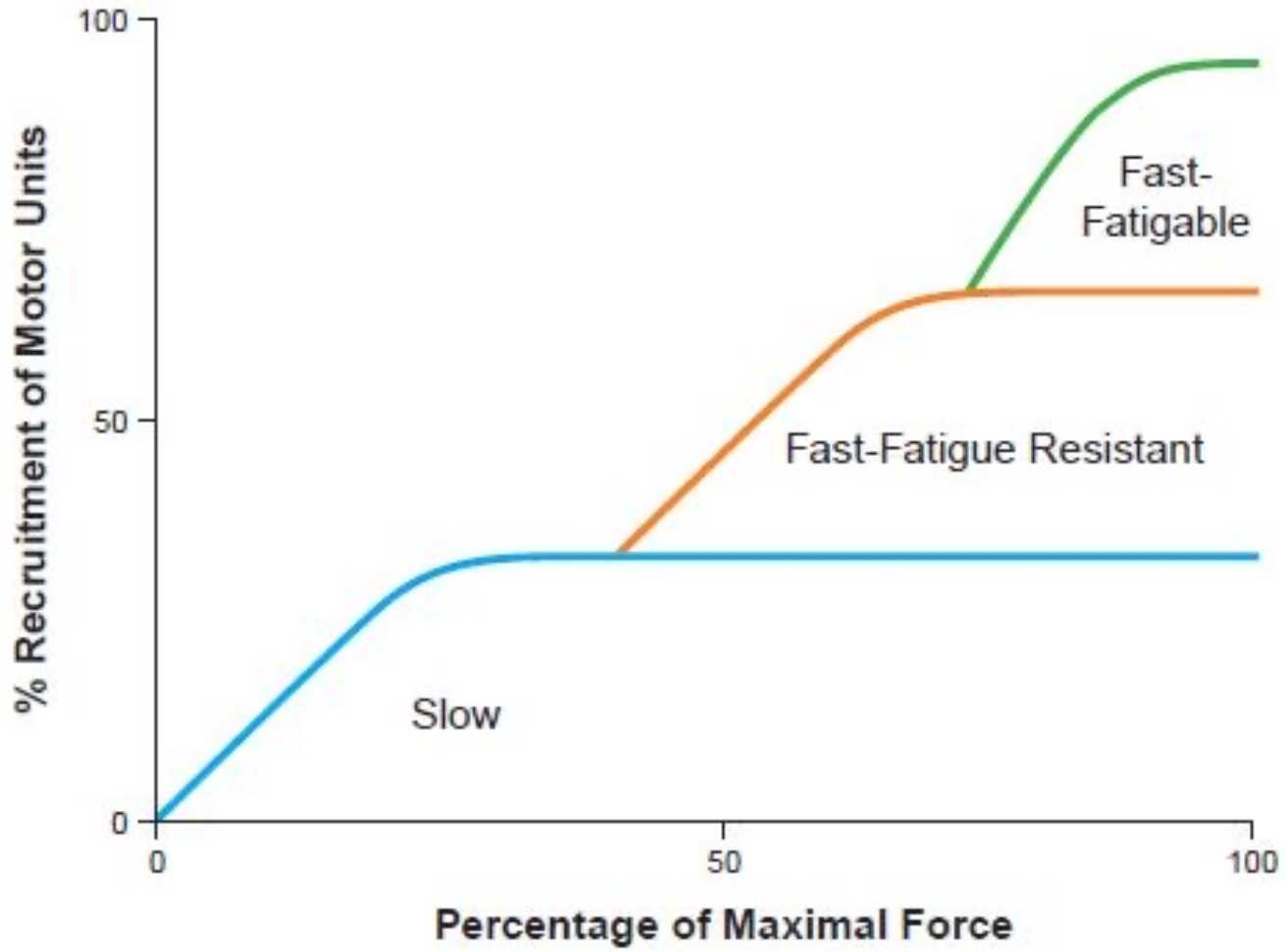
A “functional” unit of muscle contraction

Skeletal Muscle Fiber Types

	Type I Slow-Twitch Oxidative	TYPE IIA Fast-Twitch Oxidative Glycolytic	Type IIB Fast-Twitch Glycolytic
CHARACTERISTIC	**(SO)**	**(FOG)**	**(FG)**
Contraction Speed	slow	fast	fast
Fatigue rate	slow	intermediate	fast
Diameter	small	intermediate	large
ATPase concentration	low	high	high
Mitochondrial concentration	high	high	low
Glycolytic enzyme concentration	low	intermediate	high

walk run sprint

Size Principle of Motor Unit Recruitment



Muscle Signals

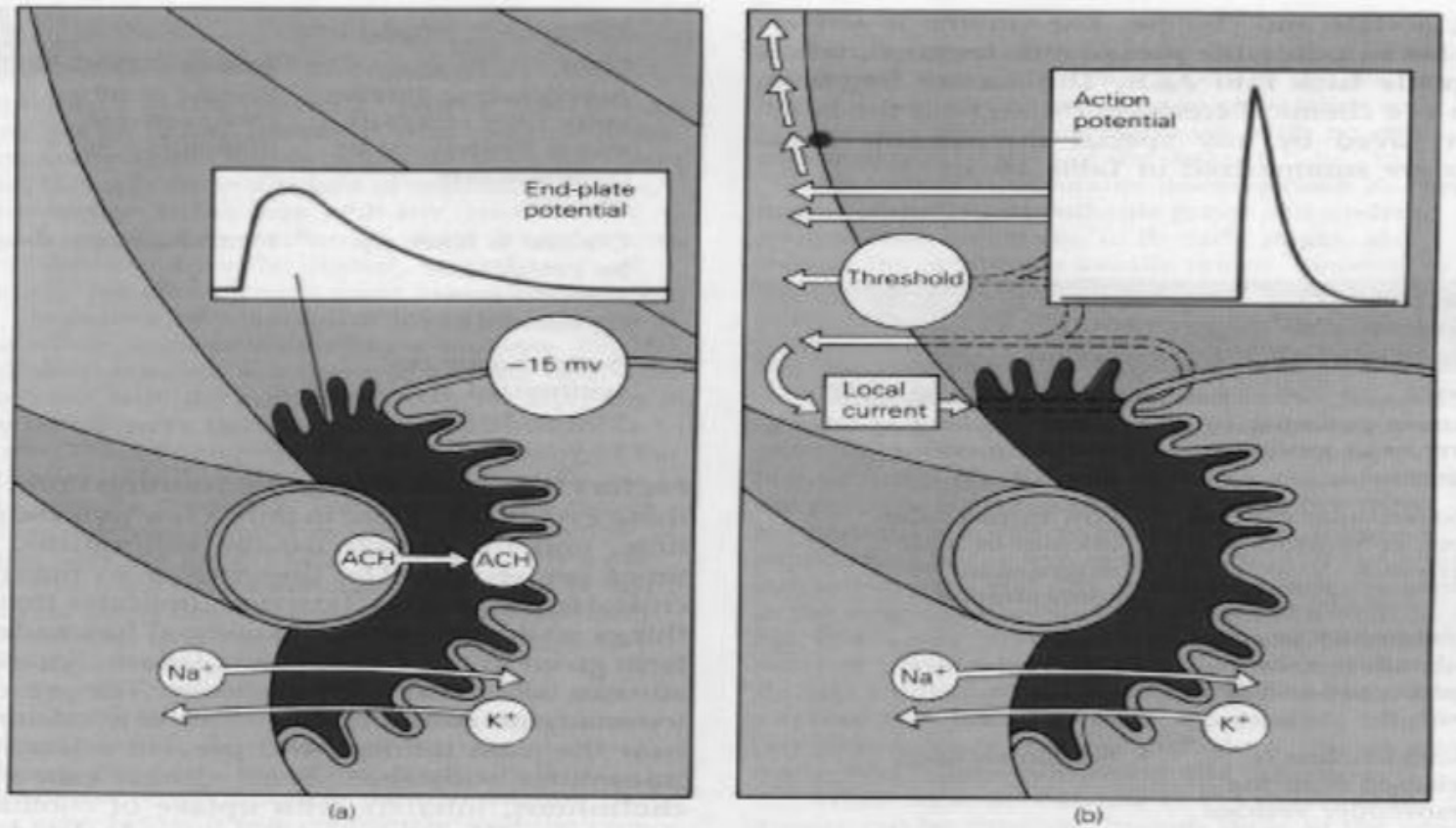
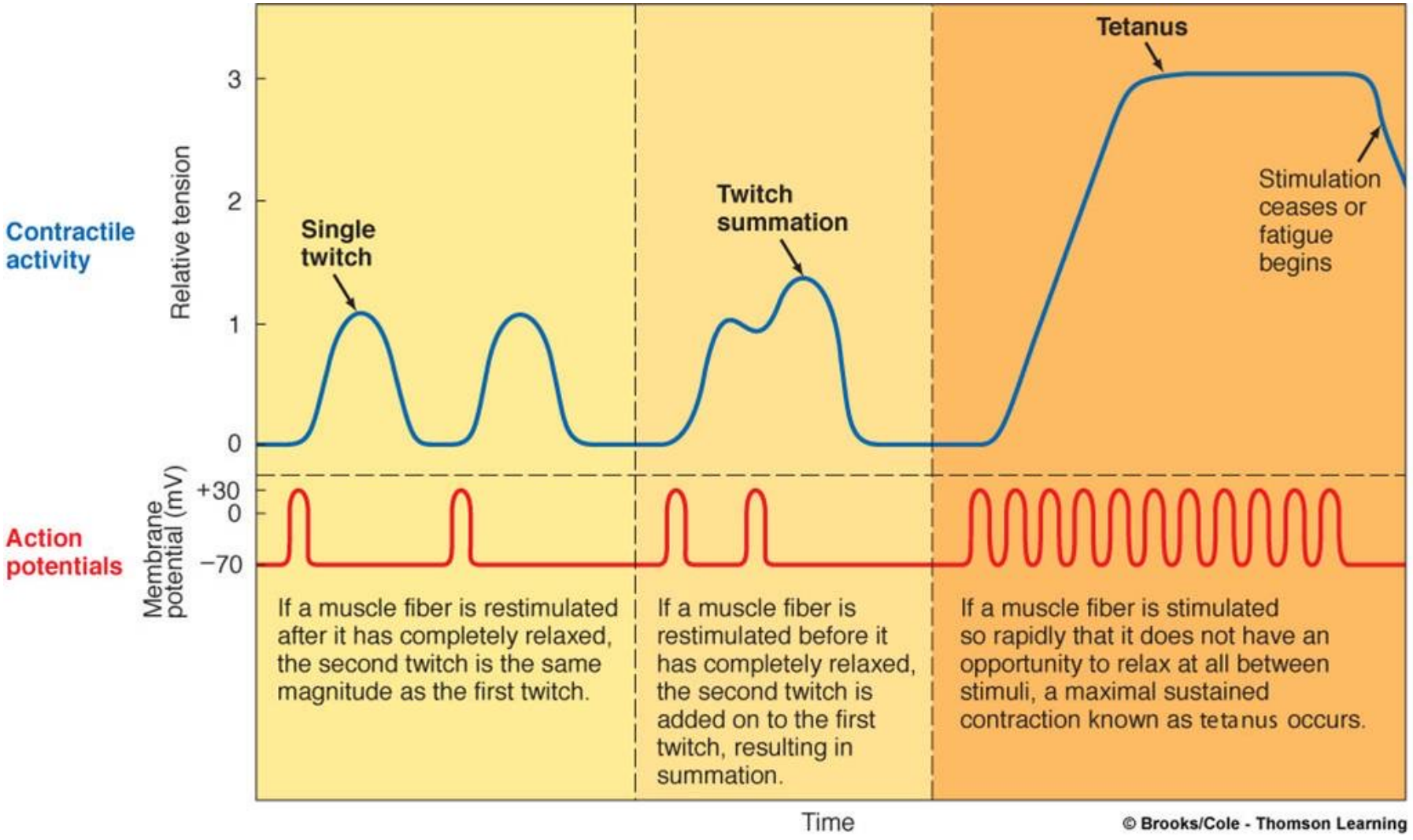
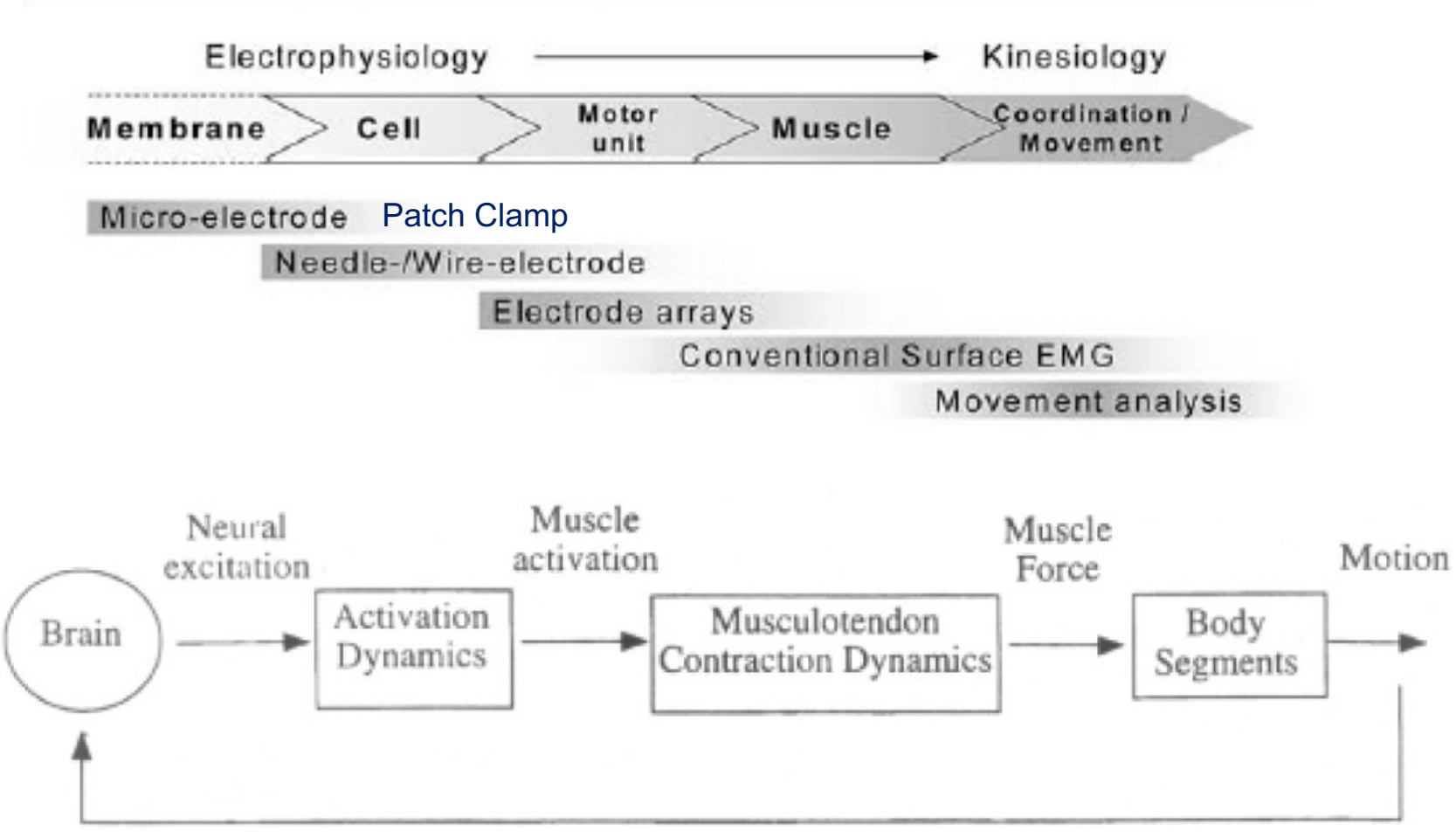


Figure 16–25 How the end-plate potential produces a muscle action potential. The region of membrane (the postsynaptic membrane) immediately opposite the axon terminal does not produce an action potential. Instead, its depolarization causes local currents to flow through the interior of the muscle cell and across the adjacent muscle cell membrane. This flow of current depolarizes the membrane to a threshold value, and it produces an action potential. This action potential then travels the length of the muscle cell membrane and enters via the t-tubule system to activate the contraction.

Muscle Signals

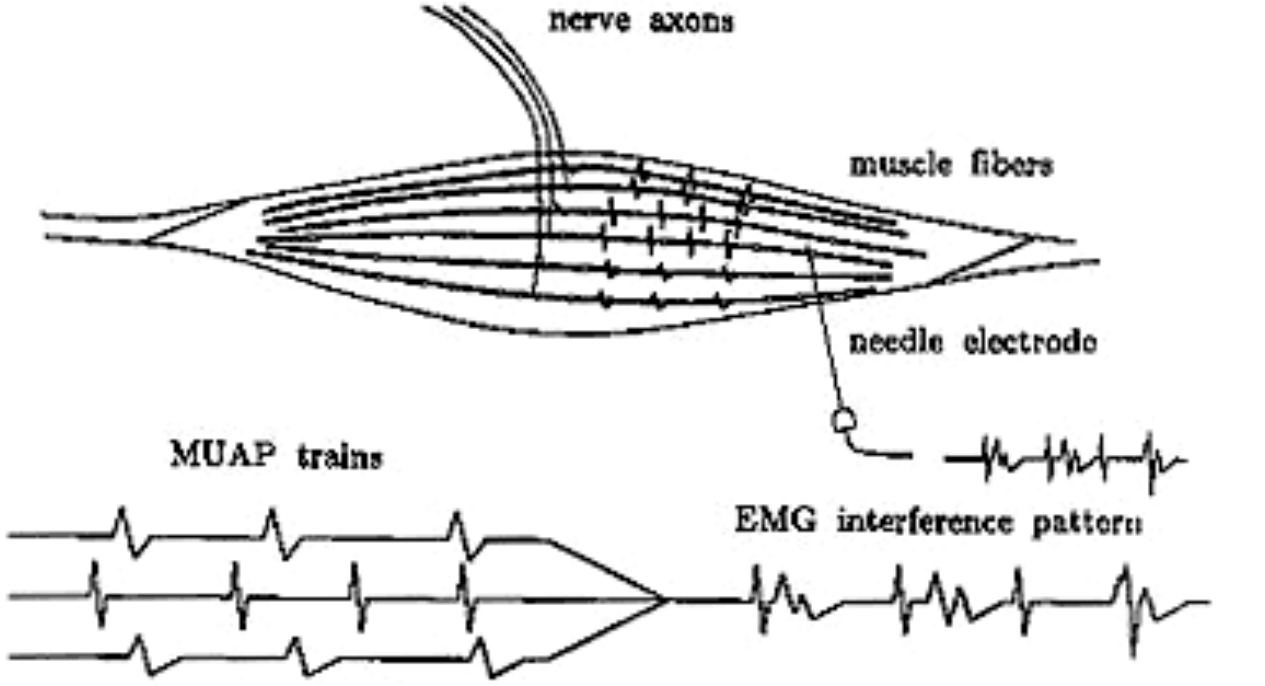


Muscle Components and Recording Techniques



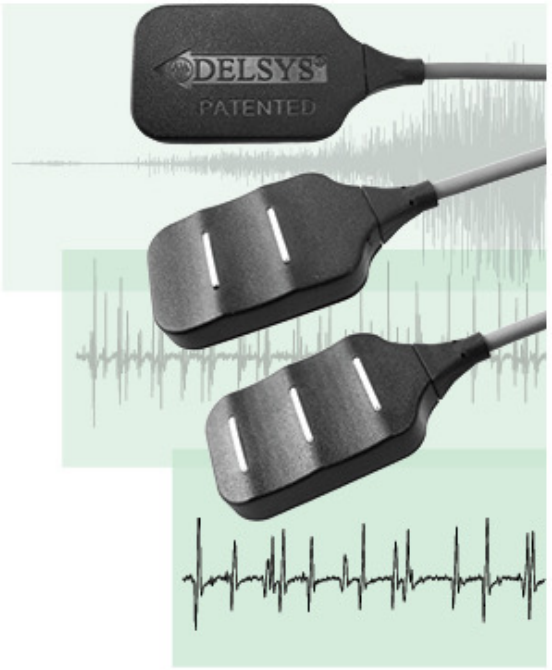
EMG Measurements and Types of Electrodes

Electromyogram: the sum of all motor unit action potentials transmitted along the muscle fibers at that point in time



www.backtohealthonline.com/emg.gif

EMG Measurements and Types of Electrodes



Surface Electrode

- Time force relationship of EMG signals
- Kinesiological/Neurophysiological/ Psychophysiological studies of surface muscles
- Interfacing an individual with an external electromechanical device
- More reproducible results than the intramuscular electrode

Intramuscular Electrode

- Kinesiological/Neurophysiological studies of deep muscles
- Limited studies of motor unit properties

Excitation-Contraction Coupling