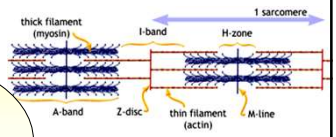
PHYSIOLOGY OF MUSCLES

Topic 2 Part 5
Cellular Physiology of Nerve and Muscle

1

2.3.1.7 describe the sliding filament mechanism of skeletal muscle contraction, indicating the roles of Ca^{++} and ATP in this process; your description should include an indication of how muscle relaxation occurs

- muscle fiber shortens because ***sarcomeres*** shorten; individual thin and thick ***filaments*** **remain the same length**
- thin filaments **slide** over thick filaments
  - ***relaxed***: only slight overlap of thick & thin filaments
  - ***contracted***: thin filaments penetrate more deeply into A band - **Z discs** pulled toward thick filaments



Overall:

distance between Z discs reduced

I bands shorten

H zones disappear

A bands move closer together, but stay same length

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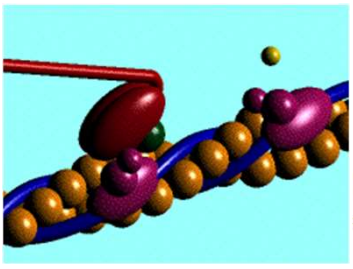
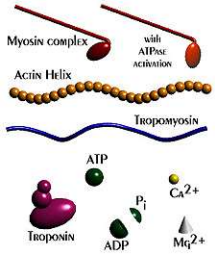
2



http://www.sci.sdsu.edu/movies/actin_myosin_gif.html



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How does sliding occur??

Stimulus to contract

↓

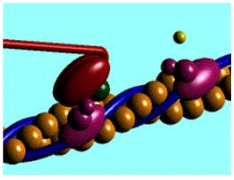
myosin cross bridges attach to actin

↓

detaches and attaches numerous times to pull thin filaments toward centre of sarcomere

↓

muscle shortens as this process occurs simultaneously in all sarcomeres



Note:

crossbridge attachment to actin requires Ca^{++}

nerve impulse increases $[Ca^{++}]$ in muscle cells

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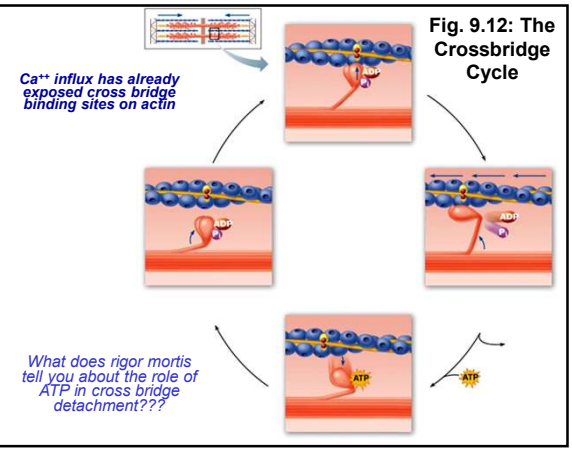
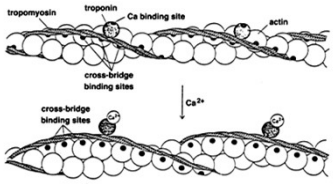


5

Details on the Mechanism

When intracellular $[Ca^{++}]$ is **low**: myosin binding sites on actin are **blocked** by tropomyosin

When intracellular $[Ca^{++}]$ is **high**: Ca^{++}binds to troponin >> shape change & brief detachment from actin >> moves tropomyosin away from myosin binding sites >> sites are **exposed**



http://physioweb.med.uvm.edu/muscle_physio/cntrctl_systm/cntrctl_troponin.htm

- A single power stroke of **all** cross bridges would give only 1% shortening;

How much muscle shortening occurs on average??

- Also, only ½ of myosin heads actively pulling at one time
- **relaxation** occurs as SR reclaims Ca^{++}

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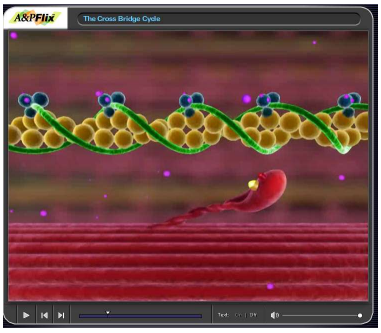
6

Chapter 9 A&P Flix: The Cross Bridge Cycle



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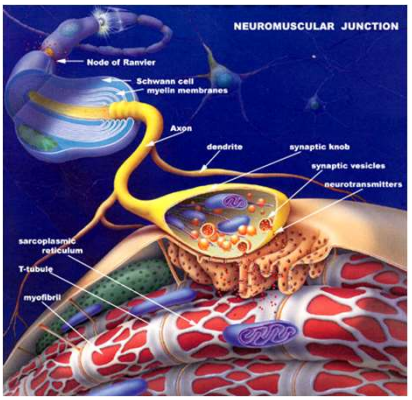


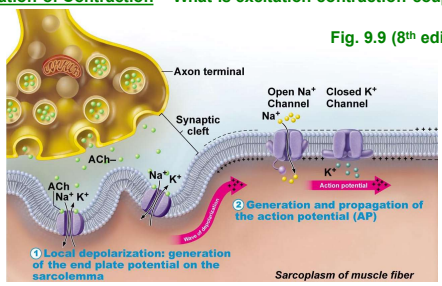
http://fig.cox.miami.edu/~cmallery/150/neuro/neuromuscular-sml.jpg

8

2.3.2.1 describe the structural organization of a neuromuscular junction; justify the latent period of excitation-contraction coupling

Regulation of Contraction – What is excitation-contraction coupling?

Fig. 9.9 (8th edition)

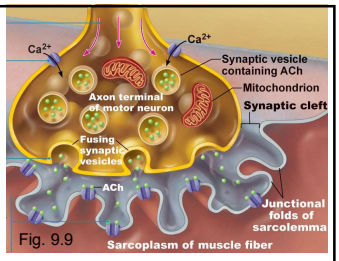


Neuromuscular junction & nerve stimulus:

- skeletal muscles are stimulated by **motor** neurons of the **somatic** ns
- 1 NMJ in ~middle of fiber - **synaptic cleft**; NT is **acetylcholine**
- **What is the motor end plate? What is an end plate potential?**
- events at nerve-muscle synapse identical to those in nerve-nerve synapse

9

Generation of an AP across the sarcolemma:



Chemically gated channels: local depolarization leads to APs in **all directions**

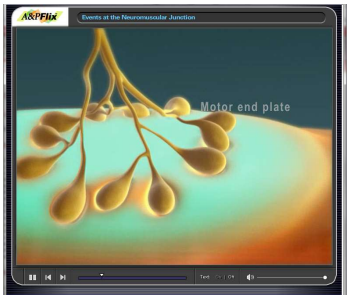
Depolarization (Na^+) followed by repolarization (K^+) as for neuron action potentials

Na^+/K^+ pump always working to restore correct ion distributions

Once initiated, AP is **unstoppable - all-or-none** response of muscle cell
AP is brief (1-2 msec); contraction can be 100 msec or more

10

A & P Flix – Chapter 9: Events at the Neuromuscular Junction

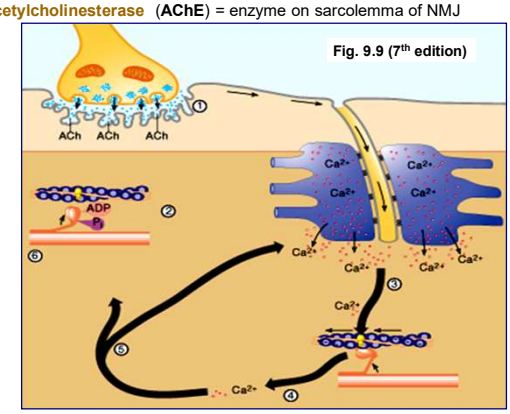


11

Destruction of acetylcholine:

- **acetylcholinesterase** (**AChE**) = enzyme on sarcolemma of NMJ

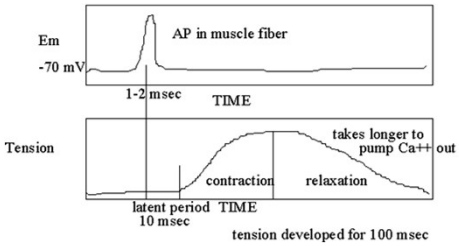
Fig. 9.9 (7th edition)



12

*What is the **latent period** of excitation-contraction coupling??*

What happens if nerve impulses arrive at the NMJ at high frequency??



http://facstaff.elon.edu/shouse/physiology/physiol14/Lecture7.html

13

IV. CONTRACTION OF A WHOLE SKELETAL MUSCLE

2.3.3.1 define motor unit; describe the influences of wave summation and motor unit summation on the contractile response of skeletal muscle; define tetanus in terms of muscular contraction

The Motor Unit

MOTOR UNIT = 1 motor neuron + all muscle fibers it supplies

motor nerve (at least 1/muscle)

↓

hundreds of motor neuron **axons**

↓

each axon to many **axonal terminals**

↓

each axonal terminal to **NMJ** of a **single muscle fiber (cell)**

- avg. no muscle fibers per neuron = 150 (range = 4 to hundreds)
- when neuron fires, **all** fibers contract

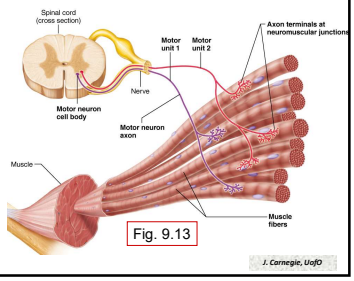


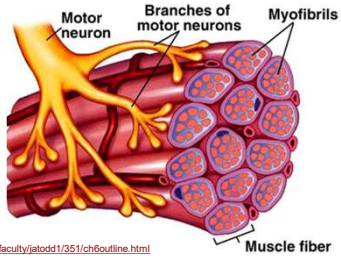
Fig. 9.13

14

Graded Muscle Responses:

Muscle responses can be graded in two ways:

1) change **speed** of stimulation
2) change **number** of motor units activated



http://academic.wsc.edu/faculty/jatodd1/351/ch6outline.html

15

1. Speed of stimulation: wave summation & tetanus:

- rapid rate of stimuli: each contraction **builds** on the previous one
- but **AP** refractory period is always honoured
- **fused tetanus:** inter-stimulus interval too short to allow inter-twitch muscle relaxation - eventually followed by **muscle fatigue**
- primary goal: **smooth, continuous** contractions

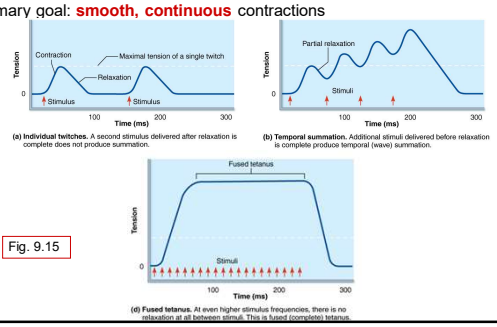


Fig. 9.15

16

2. Multiple motor unit summation:

- a means of **increasing** strength of contraction
- **threshold stimulus:** first observable response
- **maximal stimulus:** strongest stimulus that produces an increase in contractile force (more motor units recruited)
  - √ smallest motor units controlled by **most excitable** neurons
  - √ more intense stimulation recruits larger motor units
- all units can be recruited simultaneously, but usu staggered ⇒ *result is ???*

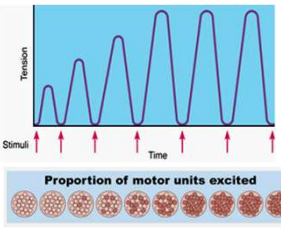


Fig. 9.13 – Recruiting more motor units

Muscle tone:

even **relaxed muscle** is a bit contracted (**tone**) due to spinal reflexes activated by stretch receptors *effects on muscles, joints, posture??*

17

***2.3.3.2** differentiate between **isotonic** and **isometric contractions,** giving an example of each*

(1) **isotonic:** muscle **changes** in length & **moves load** - *what are **concentric** vs **eccentric** isotonic contractions?*

*NB: **eccentric** contractions are 50% more forceful, use less ATP/O_2 & fewer muscle fibers but more prone to delayed-onset soreness than **concentric** contractions – e.g. calf muscle when walking up a steep hill*

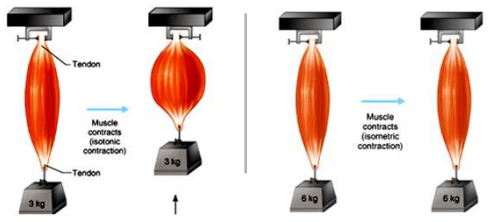


Fig. 9.15

18

(2) **isometric:** tension **increases** but muscle remains **same length**

- most body movements are a **mix** of isotonic and isometric contractions
- realize that in **isonic** contractions, the thin filaments are sliding, but in **isometric** contractions the cross bridges are generating force, but **do not move** thin filaments

Eccentric contractions are sometimes referred to as *braking* contractions.

19

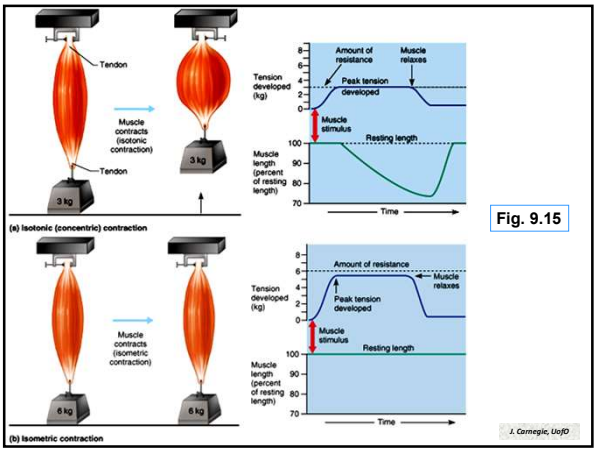


Fig. 9.15

20

1. **After ACh attaches to its receptors at the neuromuscular junction, the next step is:**
   a) K^+-gated channels open
   b) Ca^{++} binds to troponin
   c) the T tubules depolarize
   d) cross bridges attach
   e) ATP is hydrolyzed

2. **Which of these does NOT narrow when skeletal muscle contracts?**
   a) H zone
   b) A band
   c) I band
   d) sarcomere

3. _____ **is a sustained contraction.**
   a) tetanus
   b) all or none
   c) isometric
   d) twitch

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21