

## MUSCLE PHYSIOLOGY

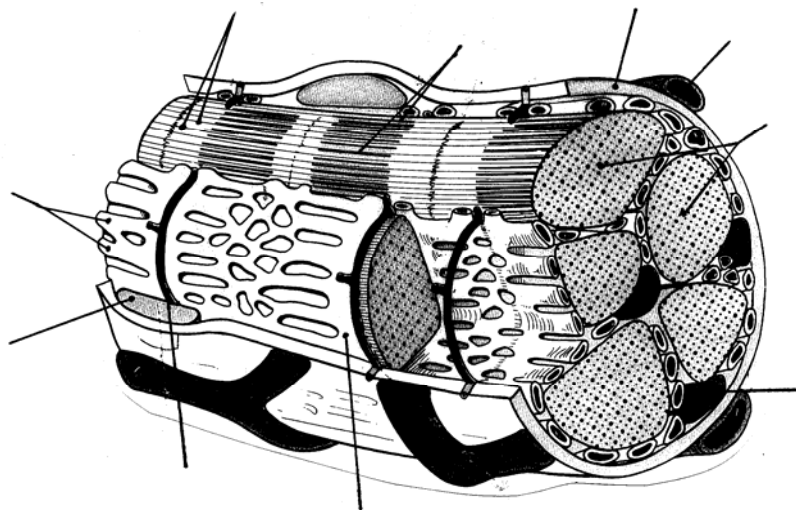
### Recall!

muscle cell =

### skeletal muscle fibers

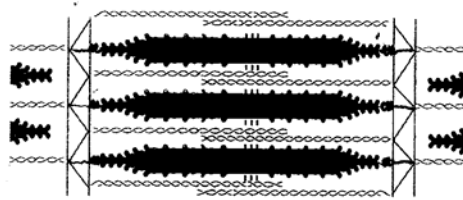
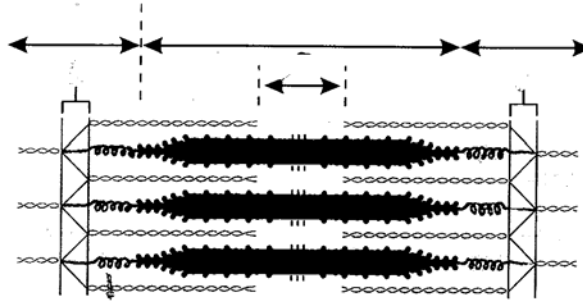
- long ( ), striated, multinucleated cells
- nerve ending contacts muscle cell at →
- plasma membrane →
- cytoplasm →
- sarcolemma penetrates cytoplasm to form (transverse tubules) → spread electrical impulse
- special endoplasmic reticulum → (stores ions)
- cells contain organized into hundreds / thousands of parallel bundles of = contractile structures

### diagram of muscle cell or 'fiber'



## myofibril

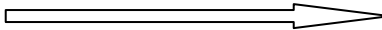
- \_\_\_\_\_ of muscle fibers
- 3 kinds of
  - \_\_\_\_\_ (thin)
  - \_\_\_\_\_ (thick)
  - \_\_\_\_\_ (elastic)
- arranged into contractile units →  
(sarcomeres shorten when contraction occurs)



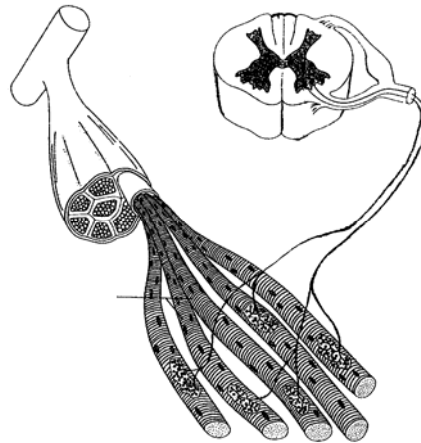
- RECALL: I bands =** actin only (thin filaments, light in colour)
- A bands =** myosin only (heavy filaments, dark in colour)
- H zone =** space between ends of actin filaments (hole in middle of sarcomere) → disappears in contracted muscle
- Z discs =** delineate ends of sarcomere (attachment of titin here)

## CONTRACTION OF MUSCLE CELLS

- skeletal muscle cells contract in response to from

motor neuron 

motor unit =



**NOTE:** some motor units have only a few muscle cells (permits fine, precise motor control); other motor units have many muscle cells (gross motor movement / powerful contractions)

### Events at neuromuscular junction

- motor neuron releases neurotransmitter (ACh release triggered by influx into neuron)
- ACh molecules bind to
- binding triggers in muscle cell

### Muscle cell action potential

- muscle cells have **transmembrane potential** (def'n)

**WHY?**

pumps

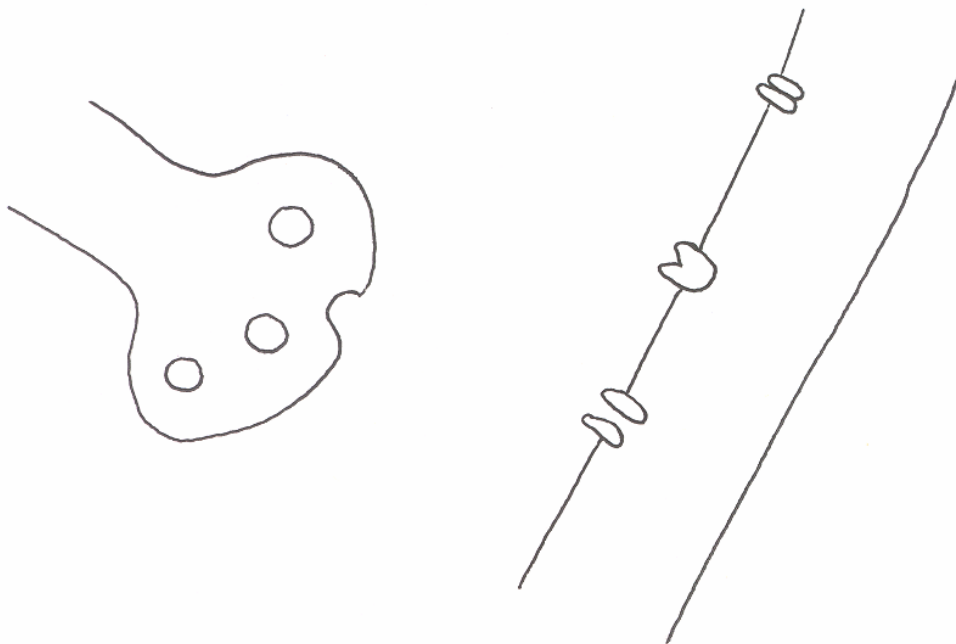
and

→ makes extracellular fluid ( )  
intracellular fluid ( )

than

**So.....** muscle cell membrane is

**THINK!** Which direction will  $\text{Na}^+$  move if  $\text{Na}^+$  gates are suddenly stimulated to open as a result of binding of ACh?

**action potential** (def'n)**Summary:**

### Excitation – contraction coupling

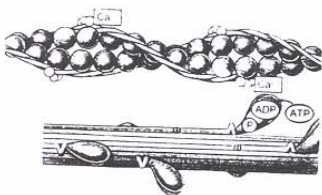
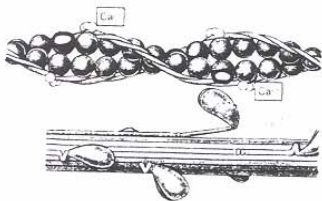
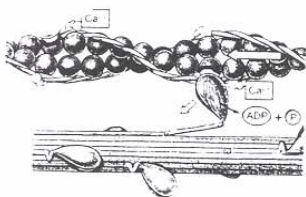
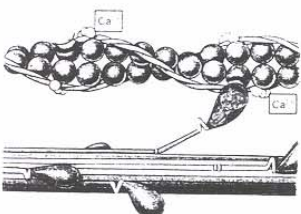
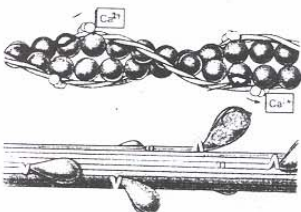
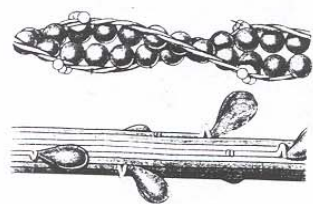
- muscle cell excitation triggers contraction

Na influx causes



over sarcolemma to spreads

triggers from cisternae of

causes between filaments

**Sliding of filaments (molecular events)**

**muscle cell contraction**

-  
- contraction continues as long as

**muscle cell relaxation**

- (no action potential)
- back into sarcoplasmic reticulum
- of muscle cell (Na<sup>+</sup>/K<sup>+</sup> transporter restores transmembrane potential)
- recoil of (assisted by gravity)

**THINK!**

Why does rigor mortis occur shortly after death?

Botulism toxin prevents ACh release. What effect would this have?

Curare blocks ACh receptors in skeletal muscle cells. What effect would this have on an animal shot with an arrow coated in curare?

Myasthenia gravis is an autoimmune disorder where the body makes antibodies to ACh receptors. What effect would this have?

**CONTRACTION OF WHOLE MUSCLE**

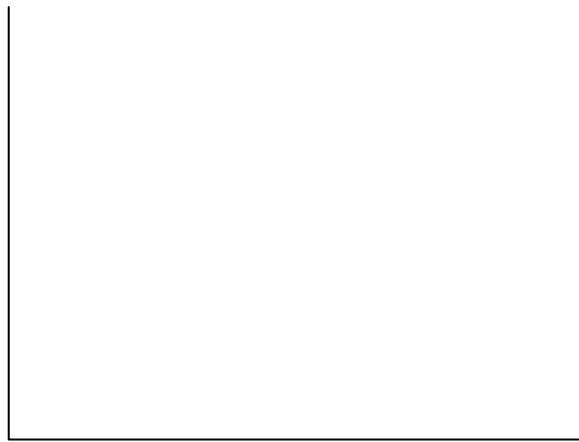
- requires simultaneous stimulation of

**muscle twitch =**

1 \_\_\_\_\_ ( t-tubules depolarize; muscle cannot respond to another stimulus)

2 \_\_\_\_\_ sarcomeres shorten

3 \_\_\_\_\_  $\text{Ca}^{++}$  transported back into cisternae of SR



**NOTE:**

**tension =**

affected by

- 
- 
-

## 1. length – tension relationship

moderate stretch

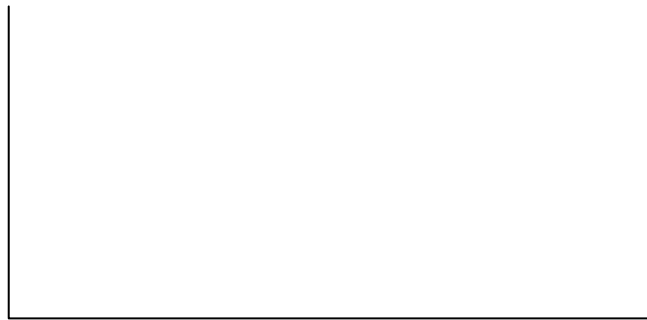
unstretched

overstretched

**NOTE:** muscles are stretched when they are attached to bone (perfect amount of stretch to permit generation of maximum tension)

## 2. strength of stimulus

- stronger stimulus →



- “ “ when a muscle first begins to contract, tension will increase somewhat even if the stimulus strength remains the same

**why?**

**NOTE:** is maintained by small asynchronous contractions of random motor units due to neural stimulation

**THINK!** What would happen to muscles in patient with injuries affecting motor neuron pathways (eg. spinal cord injuries)?

### 3. frequency of stimulus

“ “ = smooth sustained contraction (fusion of individual twitches as frequency of stimulation increases)



**NOTE:** muscle contraction is normally tetanic

#### Types of contraction

\_\_\_\_\_ tension increases but muscle does not change length

eg.

\_\_\_\_\_ tension generated as muscle changes length

eg.

2 phases

phase (as muscle shortens)

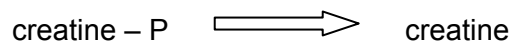
phase (as muscle lengthens)

## MUSCLE METABOLISM

- muscle contraction requires energy ( )
- ATP required for 3 steps
  - 1.
  - 2.
  - 3.

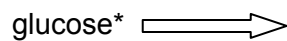
### 3 pathways of ATP synthesis ( )

1. (amino acid derivative stored in muscle)



(duration of activity )

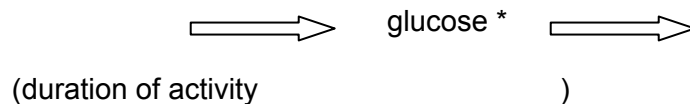
2. (no oxygen required)



(duration of activity )

**NOTE:** lactic acid diffuses into blood → (reconverted to pyruvate or glucose)

3. (requires )



\*(muscle is stored in muscle; glycogen is a polymer of glucose)

**NOTE:** all 3 metabolic pathways generate (approx. 85% of heat required to maintain normal body temperature is generated by muscle contraction)

**THINK!** Why do you 'shiver' when you are cold?

**muscle fatigue**

def'n

- (depletion of glucose, glycogen, creatine phosphate)
- build-up (lowers pH in muscle → reduces contraction efficiency)
- (especially K<sup>+</sup> loss from muscle)

**oxygen debt**

=

- metabolic processes following exercise require O<sub>2</sub>

eg.

**NOTE:** the speed of contraction, strength of contraction, and endurance of a muscle are determined by the number, size and type of muscle fibers making up the muscle (genetic limitations!)

**types of muscle fibers**

- differ in the \_\_\_\_\_ they contain
1. \_\_\_\_\_ (slow twitch oxidative / type I)
    - \_\_\_\_\_
    - \_\_\_\_\_ colour due to pigment \_\_\_\_\_ (can bind \_\_\_\_\_)
    - ATP obtained by \_\_\_\_\_
    - do not fatigue quickly → \_\_\_\_\_
  2. \_\_\_\_\_ (fast twitch glycolytic / type IIx or IIb)
    - \_\_\_\_\_
    - \_\_\_\_\_ colour (no myoglobin)
    - ATP obtained by \_\_\_\_\_ and creatine metabolism

3. \_\_\_\_\_ (fast twitch oxidative / type IIa)

- 
- colour (have \_\_\_\_\_ )
- more fatigue resistant than slow twitch fibers

**NOTE:** most muscles contain a mixture of the 3 fiber types, with postural muscles being predominantly slow twitch and muscles of the eyes and hands being predominantly fast twitch; different types of exercise / training will increase different types of muscle fibers

### Effects of exercise

muscle growth =

- primarily a result of \_\_\_\_\_ (weights!)
- myofibrils enlarge ( \_\_\_\_\_ ) →  
**(the number of muscle cells in a muscle does NOT normally increase with hypertrophy !)**
- hormone \_\_\_\_\_ facilitates muscle hypertrophy (anabolic steroids are forms of testosterone)
- fast twitch glycolytic fibers are particularly responsive to this type of training

reduced fatiguability =

- primarily result of \_\_\_\_\_
- increases \_\_\_\_\_
- intermediate and slow twitch fibers are particularly responsive to this type of training

**NOTE:** if muscle is not used regularly, it is lost ( \_\_\_\_\_ ); **“use it or lose it”**

**THINK!** What causes DOMS ( \_\_\_\_\_ )?