


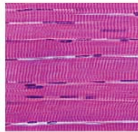
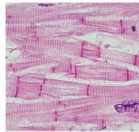
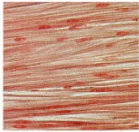


There are 3 types of muscle tissue

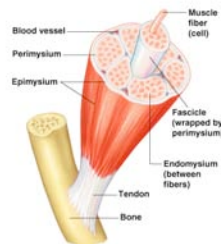
Skeletal, **cardiac**, and **smooth** muscle all share the commonality of being able to shorten, but are different in several different ways

Characteristic	Skeletal	Cardiac	Smooth
Body location	 Attached to bones or, for some facial muscles, to skin	 Walls of the heart	 Mostly in walls of hollow visceral organs (other than the heart)
Cell shape and appearance	 Single, very long, cylindrical, multinucleate cells with very obvious striations	 Branching chains of cells; uninucleate, striations; intercalated discs	 Single, fusiform, uninucleate; no striations

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Skeletal muscle cells are packaged into skeletal muscles

Cells are very large (up to 1 foot in length), and multinucleated
 Characterized by being **voluntary** (the only voluntary muscle type), but some involuntary control as well
 Has obvious **striations** (related to both structure and function)
 Has the ability to contract very forcefully, but tires easily



There are 3 types of muscle tissue

Skeletal, **cardiac**, and **smooth** muscle all share the commonality of being able to shorten, but are different in several different ways

If you keep some prefixes in mind, it will help make learning about muscles easier for you:

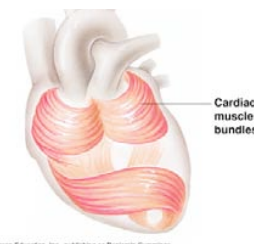
myo- and **mys-** mean “**muscle**”

sarco- means “**flesh**”

For instance, a muscle cell’s ability to contract is due to two kinds of specialized **myofilaments** (the muscle cell’s equivalent of microfilaments)

Cardiac muscle is found only in the heart

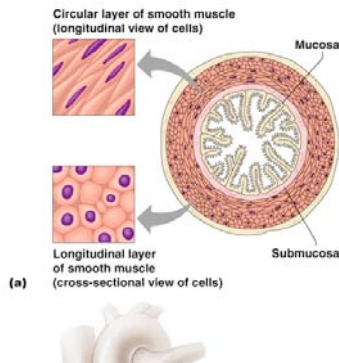
Like skeletal muscle, cardiac muscle is striated in appearance
 By most people it cannot be consciously controlled
 Muscle cells are joined by intercalated discs
 Muscle cells are also arranged in a spiral fashion
 These two features allow muscle contractions to be closely regulated
 Tends to contract at a fairly steady rate



(b)
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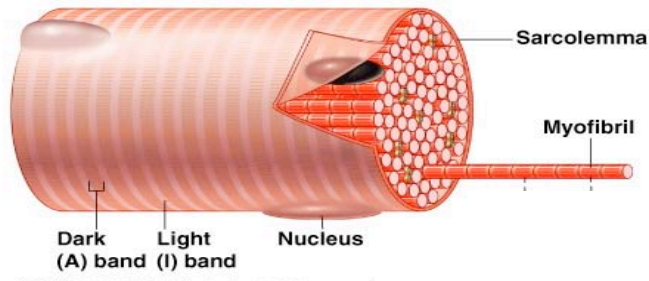
Smooth muscles is found in our visceral organs

Smooth muscle is our only muscle tissue which is **non-striated**
It tends to be found mostly on the walls of **hollow visceral organs**
We have **no voluntary control** over smooth muscle
Often found in **longitudinal and circular layers**



Skeletal muscle cells have specialized organelles

Beneath the **sarcolemma**, you can easily visualize the **Dark and Light bands**, as well as **multiple nuclei**
Myofibrils take up most of the inside of the cell, and push the nuclei towards the sarcolemma



Skeletal muscle has many functions

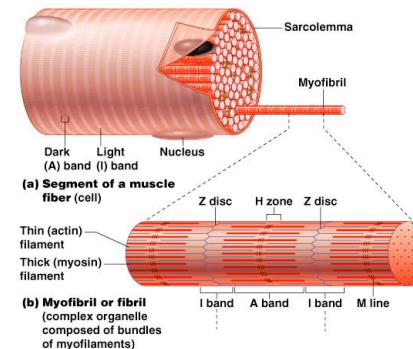
Producing movement (all muscle does this, not just skeletal muscle)

Maintaining posture—almost continuous function

Joint stabilization

Generation of heat—nearly 75% of the energy stored in ATP escapes as heat; our skeletal muscles is ~40% of our body mass, so it generates most of our heat

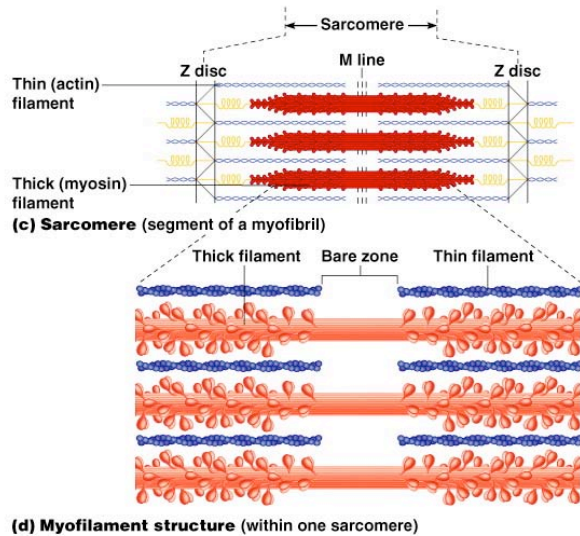
Banding reveals a lot about how a muscle functions



The myofibrils are divided into functional units called **sarcomeres**

Myofilaments within the sarcomeres produce the banding pattern

These myofilaments are **myosin (thick)** or **actin (thin)**



To contract, muscle cells must be stimulated

Because muscle cells can receive and respond to a stimulus, we consider them to be **excitable** (= responsive, irritable)

When they are stimulated, muscle cells **shorten**, or **contract**, thus they are **contractile**

Muscles can also be stretched...they are **extensible**

They also recoil and resume their original length after being stretched; they are **elastic**

To contract, muscle cells must be stimulated

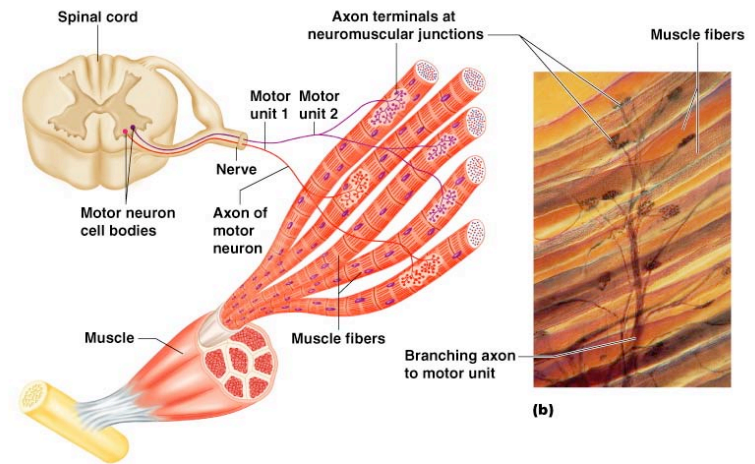
In muscle cells, the stimulus to contract is caused by a **nerve impulse**

The impulse is delivered by a type of nerve cell called a **motor neuron**

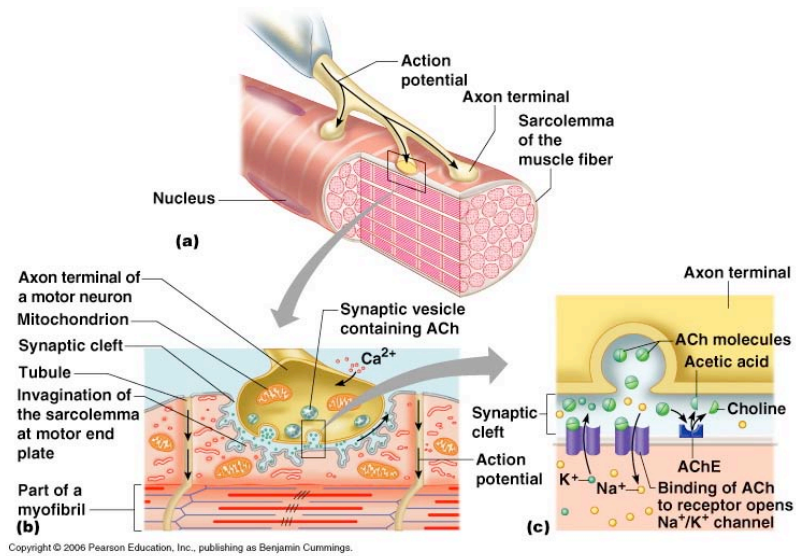
Each motor neuron innervates multiple skeletal muscle cells

1 motor neuron + all of the muscle cells it innervates = 1 motor unit

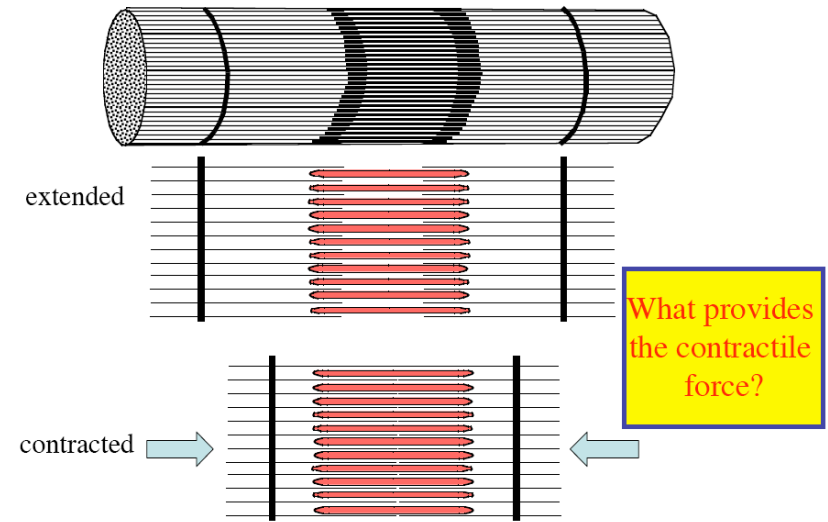
Axons form **neuromuscular junctions** with muscle cells



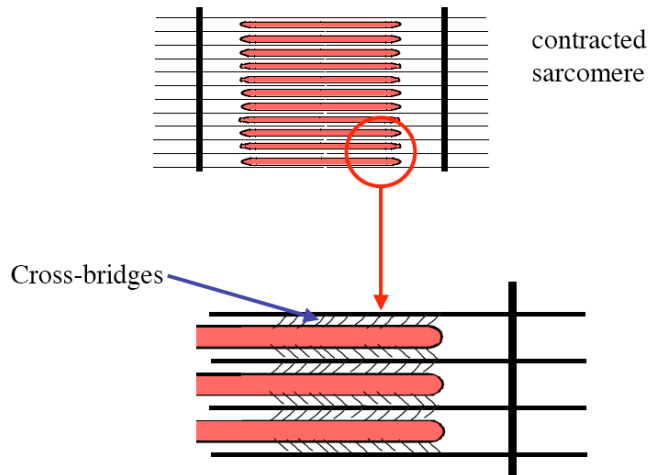
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Muscles: sliding filament model

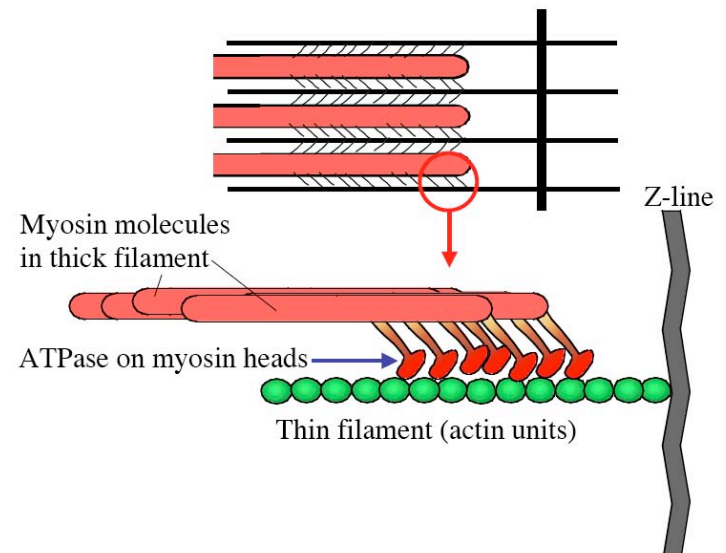


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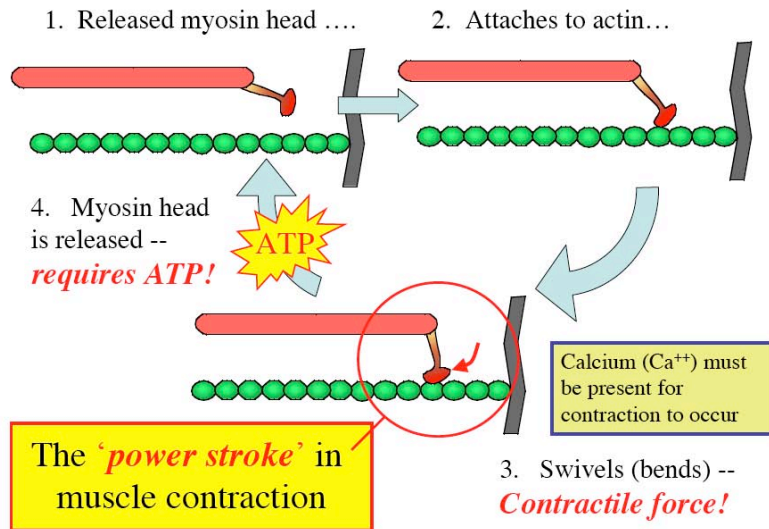


The number of cross-bridges *increases* as the sarcomere shortens.

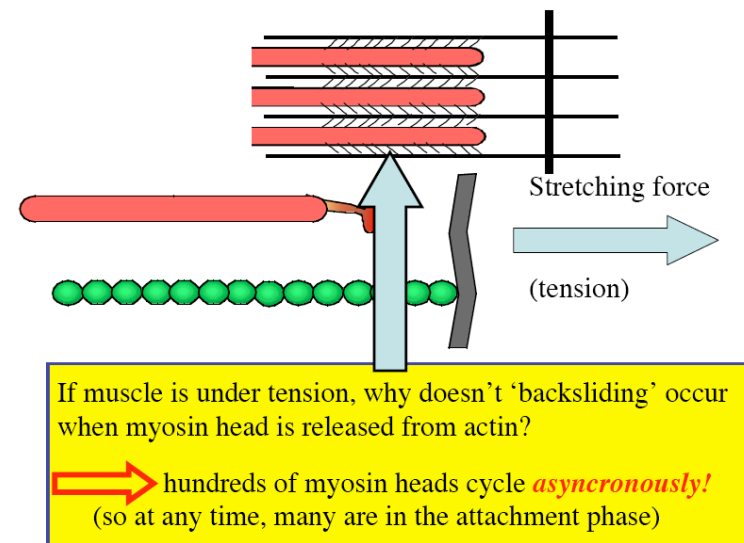
Muscles: details of contraction



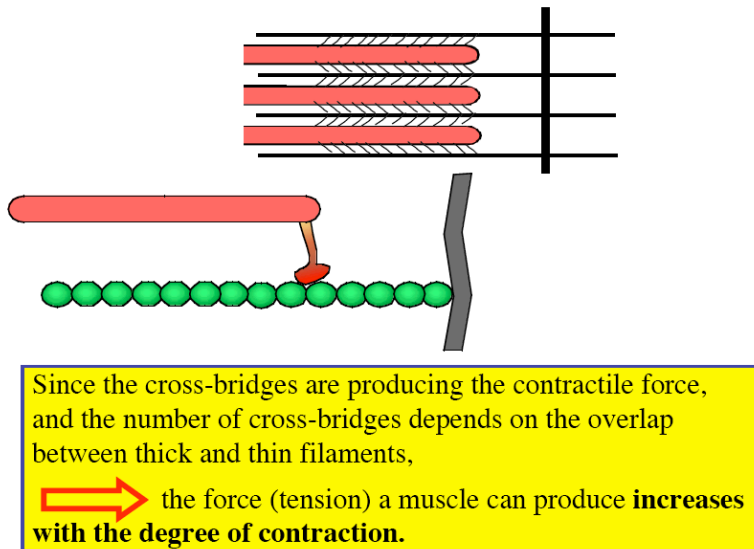
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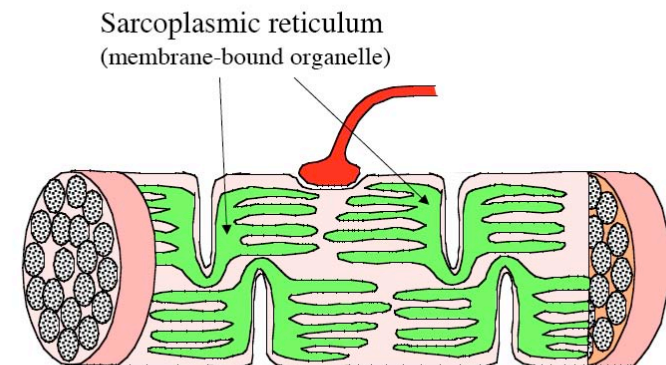
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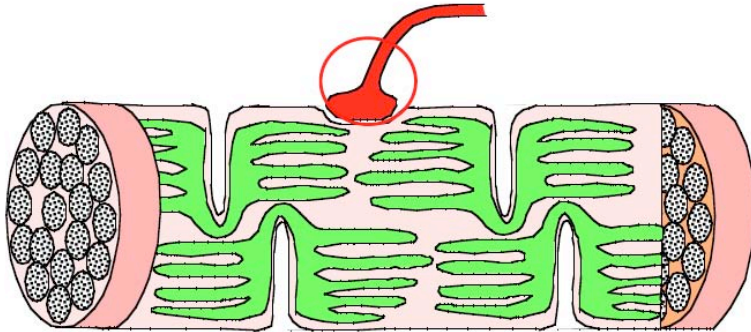
Muscles: control of contraction



A view 'inside' a muscle fiber

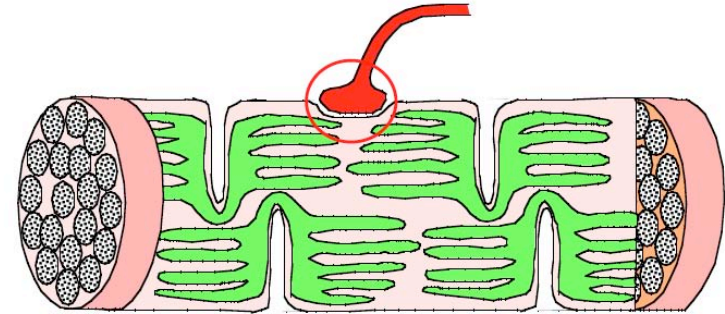
Muscles: control of contraction

1. Action potential arrives at neuromuscular junction



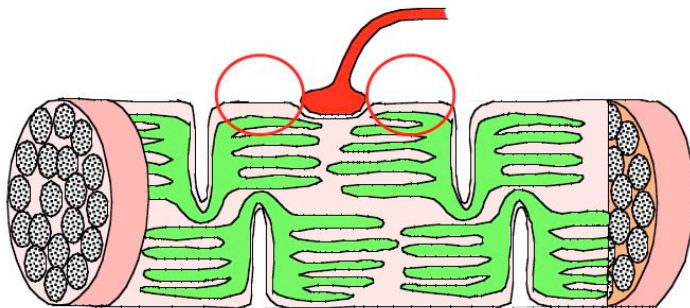
Muscles: control of contraction

1. Action potential arrives at neuromuscular junction
2. Acetylcholine released and binds to receptors



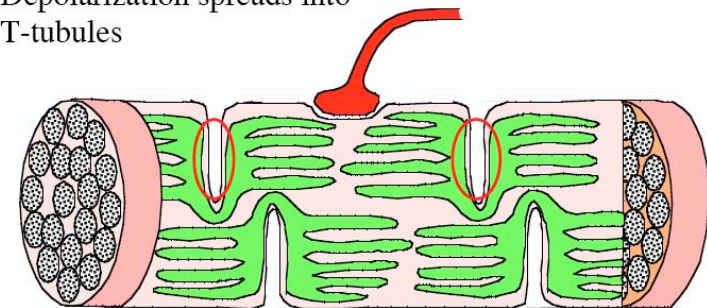
Muscles: control of contraction

1. Action potential arrives at neuromuscular junction
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3. Action potential in *muscle* cell membrane



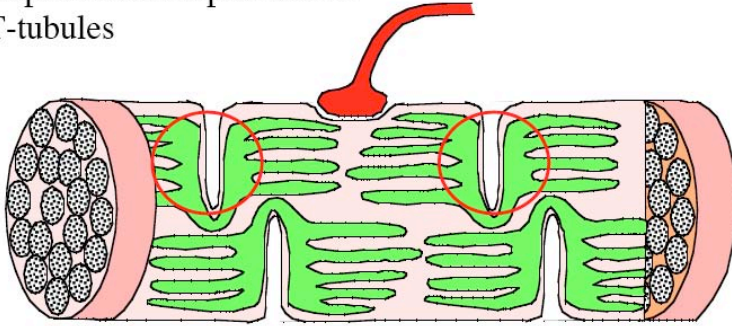
Muscles: control of contraction

1. Action potential arrives at neuromuscular junction
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3. Action potential in *muscle* cell membrane
4. Depolarization spreads into T-tubules



Muscles: control of contraction

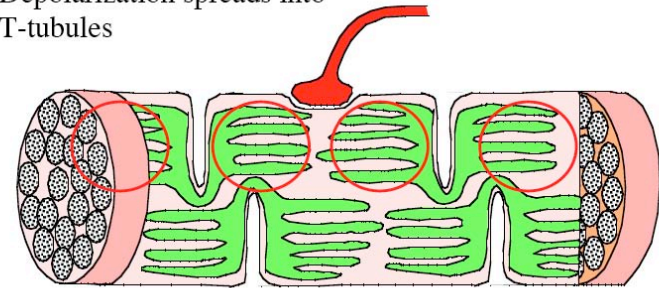
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5. Depolarization spreads to sarcoplasmic reticulum

Muscles: control of contraction

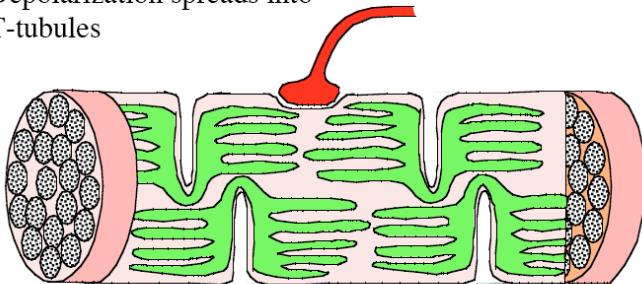
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6. SR releases Ca^{++} , which diffuses to myofibrils

Muscles: control of contraction

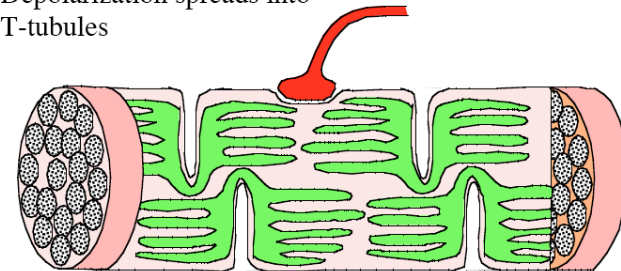
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7. Ca^{++} triggers contraction (allows myosin ATPase to work)
8. Ca^{++} reabsorbed into SR (active transport) to complete the cycle

Muscles have different degrees of shortening

An individual muscle cell will always react in the same way to a nervous stimulus (all-or-none principle)

But different #s of cells are stimulated in response to different conditions

This is called a **graded response**

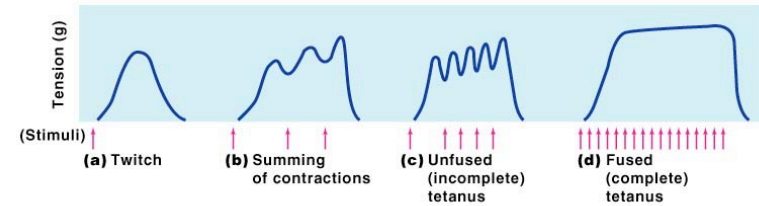
Graded responses can be produced in 2 ways:

- (1) Changing the **frequency** of muscle stimulation
- (2) Changing the **number of muscle cells** being stimulated at once

Muscles have different degrees of shortening

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Muscles: control over movement

What determines the precision of a movement?

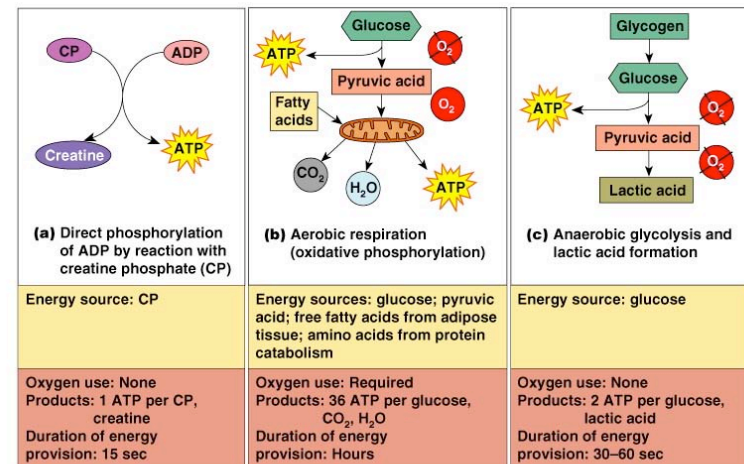
- a single motor neuron, and all the muscle fibers it innervates is a **motor unit**
- some motor units have grades contractions (related to action potential frequency)
- in other muscle types, each motor unit is 'all or nothing', so when the neuron transmits an action potential, all the muscle fibers attached to it will contract **fully**.
- muscles control the degree of contraction by recruiting different **numbers of motor units**:

More motor units active = greater contraction

- so the **total number of motor units** – *not* the size of the muscle – determines the precision of the contraction

- leg muscles: big, powerful, but not very precise
- finger or lip muscles: small, weak, but extremely precise

Where does the energy for muscle contraction come from?



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Types of contractions & muscle tone

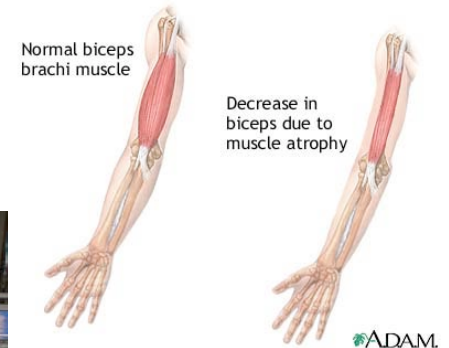
Isotonic contractions involve muscle shortening

Isometric contractions build tensions, but no sliding occurs

Muscle tone: continuous, partial contractions in your muscle; different motor units in your muscle are stimulated in a systematic way

Muscle disuse

= muscle atrophy



Specialized muscles for different jobs

Vertebrate striated muscle comes in a wide variety of types. Two basic forms are:

• 'fast-twitch' muscle (white muscle)

• 'slow-twitch aerobic' muscle (red muscle)

Specialized for burst activity:

- fast, all-or-nothing
- few mitochondria
- sparse blood supply
- fatigues quickly

Specialized for endurance activity:

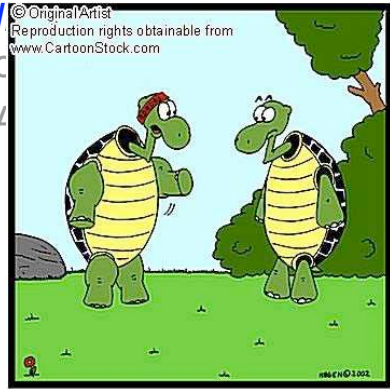
- slow, graded contractions
- rich in mitochondria
- myoglobin (hence, red), large blood supply
- more resistant to fatigue

Striated muscle is usually very responsive to conditioning

Aerobic conditioning



Resistance training



Body-building is great,
unfortunately, now I'm stuck in my shell...

size (increased # of
not muscle cell number
of connective tissue



Naming of Skeletal Muscles

- Direction of muscle fibers
 - Example: *rectus* (straight)
- Relative size of the muscle
 - Example: *maximus* (largest)

Naming of Skeletal Muscles

- Location of the muscle
 - Example: many muscles are named for bones (e.g., *temporalis*)
- Number of origins
 - Example: *triceps* (three heads)

Naming of Skeletal Muscles

- Location of the muscle's origin and insertion
 - Example: *sterno* (on the sternum)
- Shape of the muscle
 - Example: *deltoid* (triangular)
- Action of the muscle
 - Example: *flexor and extensor* (flexes or extends a bone)

Muscular dystrophy

Group of congenital muscle-destroying diseases

Muscles enlarge due to increased fat and connective tissues; but muscle fibers atrophy

Duchenne's muscular dystrophy: affects almost all males from 2-6 years old

Cause = sarcolemmal degeneration

No cure

Myasthenia gravis

Characterized by drooping eyelids, difficulty swallowing/talking, generalized weakness

Shortage of ACh receptors at neuromuscular junction

Sometimes blood contains antibodies to ACh receptors (autoimmune disease?)

Death usually occurs as a result of the inability of the respiratory system to function

Development of the muscular system

In utero muscles are laid down, and the nervous system controls it by 16 weeks of pregnancy

At birth, baby's fine motor control is not developed

Control is gained *proximal --> distal*

The muscular system is very resistant to infection (because of large blood supply)