

Muscle Contraction

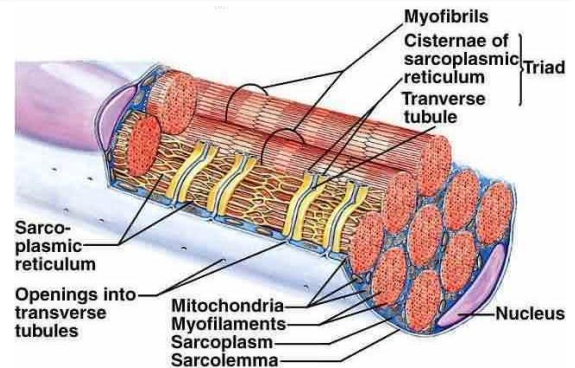
HASPI Medical Anatomy & Physiology 09b

Lab Activity

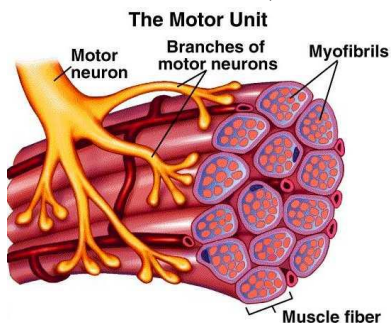
Background

Muscle Cell Structure

Muscle cells are specialized to contract. An individual muscle is actually a bundle of hundreds to thousands of long cylindrical muscle fibers or cells. The cell membrane of muscle cells is called the sarcolemma, the cytoplasm is the sarcoplasm, and the endoplasmic reticulum is modified into the sarcoplasmic reticulum (SR). Channels from the sarcolemma into the sarcoplasm and SR are called transverse (T) tubules. The T tubules allow for electrical impulses from motor neurons to be channeled directly to the SR, causing it to release calcium ions and initiate a contraction. Muscle cells are made up of bundles of myofibrils that contain the contracting units, called sarcomeres, made up of two main proteins - myosin and actin.



http://fau.pearlshes.com/anatomy/Chapter%2014/Chapter%2014_files/AP_I_7.jpg



The Motor Unit

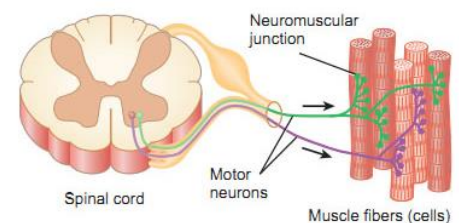
Motor neurons connect to skeletal muscles to control movement. Each motor neuron actually controls a group of muscle cells called a motor unit. All of the cells in the motor unit will be stimulated by the motor neuron at the same time. Movements that need fine motor skills, like writing with a pencil, have only a few muscle cells for each motor unit, which allows for precision. Larger movements, like picking up a bag, have many muscle cells for each motor unit.

http://www.exerbotics.com/storage/motor-unit-lq.jpg?SQUARESPACE_CACHEVERSION=1314629974992

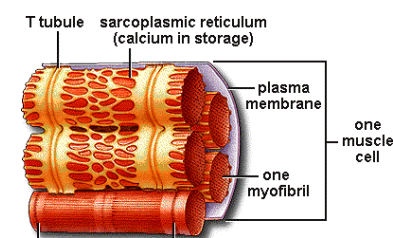
Muscle Contraction

A muscle contraction is a complicated cycle and can differ according to the type of contraction and the type of muscle tissue. The following chart describes and diagrams the steps of a muscle contraction according to the sliding filament theory.

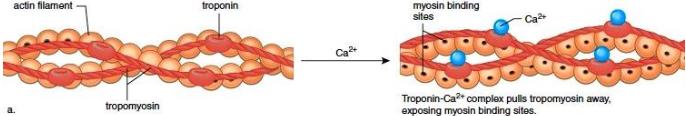
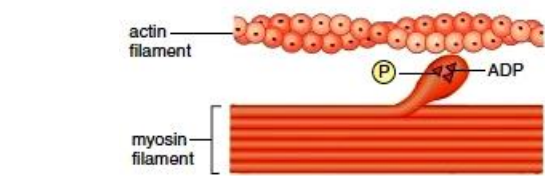
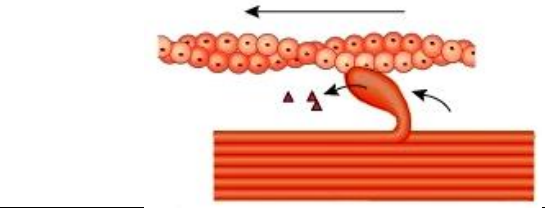
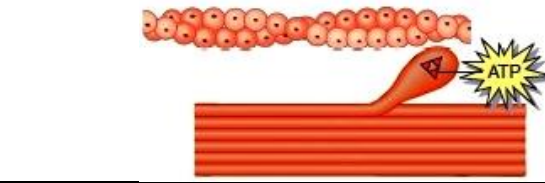
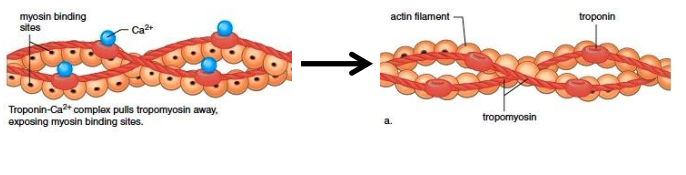
Steps of a Muscle Contraction	
1	The brain or spinal cord sends an impulse to the muscle.
2	The impulse travels down the motor neuron and reaches a neuromuscular junction where it releases acetylcholine, which triggers the impulse in the muscle.
3	The impulse travels through the plasma membrane (sarcolemma) and down T tubules surrounding the myofibrils.
4	As the impulse passes through the T tubules, it causes the sarcoplasmic reticulum (SR) surrounding the T tubule to release calcium ions (Ca^{2+}) into the sarcoplasm, eventually reaching the sarcomere.



<http://antranik.org/wp-content/uploads/2012/04/motor-unit-somatic-motor-neuron.jpg>



<http://www.student.loretto.org/humanbiology/BioLinks/chp4/media/c212f2.gif>

5	The Ca^{2+} binds to troponin located on the actin filament, causing tropomyosin to move and expose binding sites for myosin.	
6	The myosin head now binds to actin and forms a crossbridge.	
7	ADP and P_i are released from myosin, which causes the myosin to move. This movement is called the power stroke.	
8	ATP binds to myosin causing it to release the actin and reverting ATP into ADP and P_i . The myosin is now ready to form another crossbridge and the cycle of contraction will continue until the impulse stops.	
9	Once the impulse stops, Ca^{2+} is released from troponin causing tropomyosin to cover the binding sites and prevent contraction. Ca^{2+} returns to the SR and waits for another impulse. This is relaxation.	

<http://encyclopedia.lubopitko-bq.com/images/calcium%20and%20myosin%20in%20muscle%20contraction.jpg>

Contraction Abnormalities

There are several disorders related to muscle contraction, and related medical terminology. The following terms are used when describing abnormal movements or actions that all start with disorder of the muscle contraction mechanism.

- **Ataxia** – inability to make coordinated movements
- **Bradykinesia** – stiff and slow movements
- **Choreoathetosis** – continuous random movements
- **Dystonia** – sustained muscle contractions
- **Myoclonus** – rapid and brief jerking contractions
- **Paroxysmal dyskinesias** – sudden abnormal involuntary movements
- **Spasticity** – increase in muscle stiffness
- **Tics** – repetitive complex involuntary movements
- **Tremor** – rhythmic back-and-forth shaking of a muscle

McKinley and O'Laughlin. 2012. Action Potentials and Muscle Contractions. Human Anatomy, The McGraw-Hill Company, The Online Learning Center.

UCSD. 2006. Types of Contractions. Muscle Physiology, National Skeletal Muscle Research Center, UCSD, www.muscle.ucsd.edu.

Materials

Slides (3)	Fresh meat (muscle)	Ruler
Dissecting pan	Ringer's solution	Paper towels
Scalpel	ATP solution	Timer
Forceps	1% Glucose solution	Calculator

Procedure

Part A. What is Happening When a Muscle Contracts?

What is happening within the muscle cells and tissues when a muscle contracts is extremely complex. Animations can help us better understand this concept.

Go to the following website: *Molecular Mechanisms of Muscle Contraction* (whfreeman)

<https://tinyurl.com/z97jm5b>

Click on the animation tab at the top of the page. Choose the step-through version at the bottom of the animation. Answer the following questions as you watch the muscle contraction animation.

Muscle Contraction Animation		
	Question	Answer
Muscle Cell Structure	What are myofibrils? How are they organized into sarcomeres?	
	What two protein filaments are found in the sarcomere?	
	How are the Z line and titin part of the sarcomere?	
	Draw a sarcomere and label the myosin, actin, Z-line, and titin.	
	What is the sliding filament theory?	

Steps of a Muscle Contraction

Step 1	What triggers a contraction?	
Step 2	What neurotransmitter is released at a neuromuscular junction?	
Step 3	Where does the electrical signal propagate or travel?	
Step 4	What is released from the sarcoplasmic reticulum as the action potential passes through the T tubules?	
Step 5	Where does the calcium travel?	
Step 6	What two proteins are found on actin filaments?	
	What is bound to the myosin heads?	
Step 7	What happens when calcium binds to troponin?	
Step 8	Onto what does the myosin head bind to? What is formed?	
Step 9	What happens to P_i and ADP when myosin binds?	
Step 10	What is the power stroke?	
Step 11	What happens when ATP binds to the myosin head?	
Step 12	What happens after the action potential ceases?	

Return to the animation page and watch the narrated version to link all of the steps together.

Part B. Observing a Muscle Contraction

Now that you have a better understanding of what is happening in muscle cells and tissues during a muscle contraction, let us see if we can make one contract! In this lab you will investigate what happens when fresh muscle tissue is exposed to ATP and glucose.

Directions

		when complete
Step 1	Obtain three microscope slides and label the slides A, B, and C.	
Step 2	Get a dissecting pan, a scalpel, forceps, a ruler, and a small piece of fresh muscle (meat).	
Step 3	Use the scalpel and forceps to cut three VERY THIN strips of muscle. Cut the strips parallel to the direction of the muscle fibers (if it is difficult to pull apart or cut, it is the wrong direction). The strips should be less than 1 mm in width and anywhere from 20-30 mm in length.	
Step 4	Use the forceps to transfer the thin muscle strips onto each slide and add 4-5 drops of Ringer's solution to cover the strips. Ringer's solution is a saline solution similar in concentration to tissue fluid.	
Step 5	Use the forceps to orient each muscle strip in a straight line. Do not pull or stretch the tissue. Tilt the slide and drain off excess solution using a paper towel.	
Step 6	Lay slide A over the ruler and measure the length of the muscle strip. Record the length in Table 1 in millimeters in the "Before" column. Repeat this measurement and record for slides B and C.	
Step 7	Add 3-5 drops of ATP solution to slide A. Make sure the solution is spread evenly along the length of the muscle strip.	
Step 8	Add 3-5 drops of 1% glucose solution to slide B. Make sure the solution is spread evenly along the length of the muscle strip.	
Step 9	Slide C will be left alone to act as the Control.	
Step 10	Leave each slide alone for at least 5 minutes.	
Step 11	Measure the length of the muscle fiber on each slide and record the measurements in Table 1 in the "After" column.	
Step 12	Use the following equation to determine the percent of contraction: $\% \text{ Contraction} = \frac{\text{Before Length} - \text{After Length}}{\text{Before Length}} \times 100$	
Step 13	Record the percent of contraction in Table 1 for each slide.	

Table 1. Percent of Contraction

Slide	Before Length (mm)	After Length (mm)	Percent of Contraction
A <i>ATP solution</i>			
B			

Glucose solution			
C Control			

Analysis Questions - on a separate sheet of paper complete the following

1. What was the purpose of using Ringer's solution on the muscle tissue?
2. Why might muscle tissue that is not fresh yield no results?
3. What was the purpose of the control?
4. If there was any contraction of the control muscle tissue, what might that say about your results?
5. Which slide showed the greatest percentage of contraction? Is this what you thought would occur? Why or why not?
6. Glucose is considered the body's energy source for muscle contractions. Did your results support this concept? Hypothesize why or why not.
7. How did the ATP solution affect the muscle tissue? Hypothesize why this happened.
8. **CONCLUSION:** In 1-2 paragraphs summarize the procedure and results of this lab.

Review Questions - on a separate sheet of paper complete the following

1. Describe the organization of a muscle.
2. What is the sarcolemma?
3. What is the sarcoplasm?
4. What is the sarcoplasmic reticulum?
5. What are T tubules?
6. What are myofibrils?
7. What proteins make up the sarcomere?
8. What is the motor unit?
9. How are motor units different in muscles that need fine motor movement compared to those that require larger movements?
10. Describe or draw and label the 9 steps of a muscle contraction according to the sliding filament theory.
11. What is the purpose of calcium in a muscle contraction?
12. What is the power stroke?
13. What causes the muscle cell to relax?
14. What is ataxia?
15. What is dystonia?
16. What are tremors?