

PEER-LED TEAM LEARNING ANATOMY & PHYSIOLOGY

WORKSHOP MODULE 9: MUSCLE EXCITATION AND CONTRACTION

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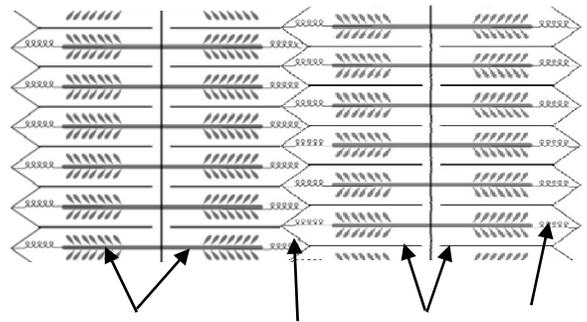
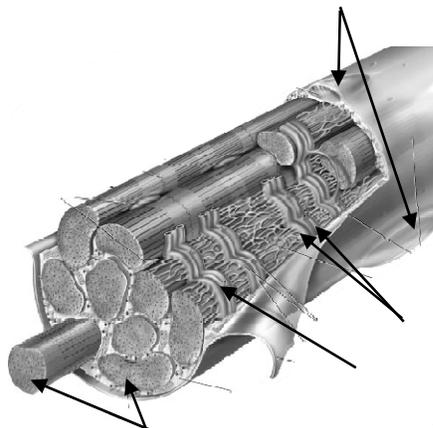
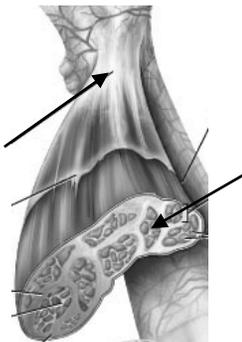
I. Introduction

Intuitively we know that the parts that make a car move are hidden under the hood. The same is true for contracting muscle. Though we are unaware of it, muscle contraction is really made possible by small units of muscle (called sarcomeres) found in each muscle cell (called a muscle fiber). To understand muscle contraction on a large scale, we will have to talk about how the signal arrives at the muscle cell, how the signal spreads along the muscle cell, and how the sarcomeres in the muscle move to cause contraction. This workshop is designed to guide you through the steps of muscle excitation and contraction and introduce you to the hidden mechanisms under the hood (so to speak).

Prepare for your workshop by reading in your textbook (Chapter 10: 326-328 and Chapter 11: 408-37) and completing the Pre-Workshop Activities below. Also it's a good idea to review the previous workshop modules (membrane transport and resting membrane potential) before you tackle this one. Show your work in these pages.

II. Pre-Workshop Activities

Activity A. Label the arrows in the following diagrams. How do the diagrams relate to one another?



Activity B. Define the following terms. Use your own words where possible.

sarcomere

myofibrils

fascicles

sarcolemma

sarcoplasmic reticulum

motor end plate

motor unit

acetylcholine

neurotransmitter

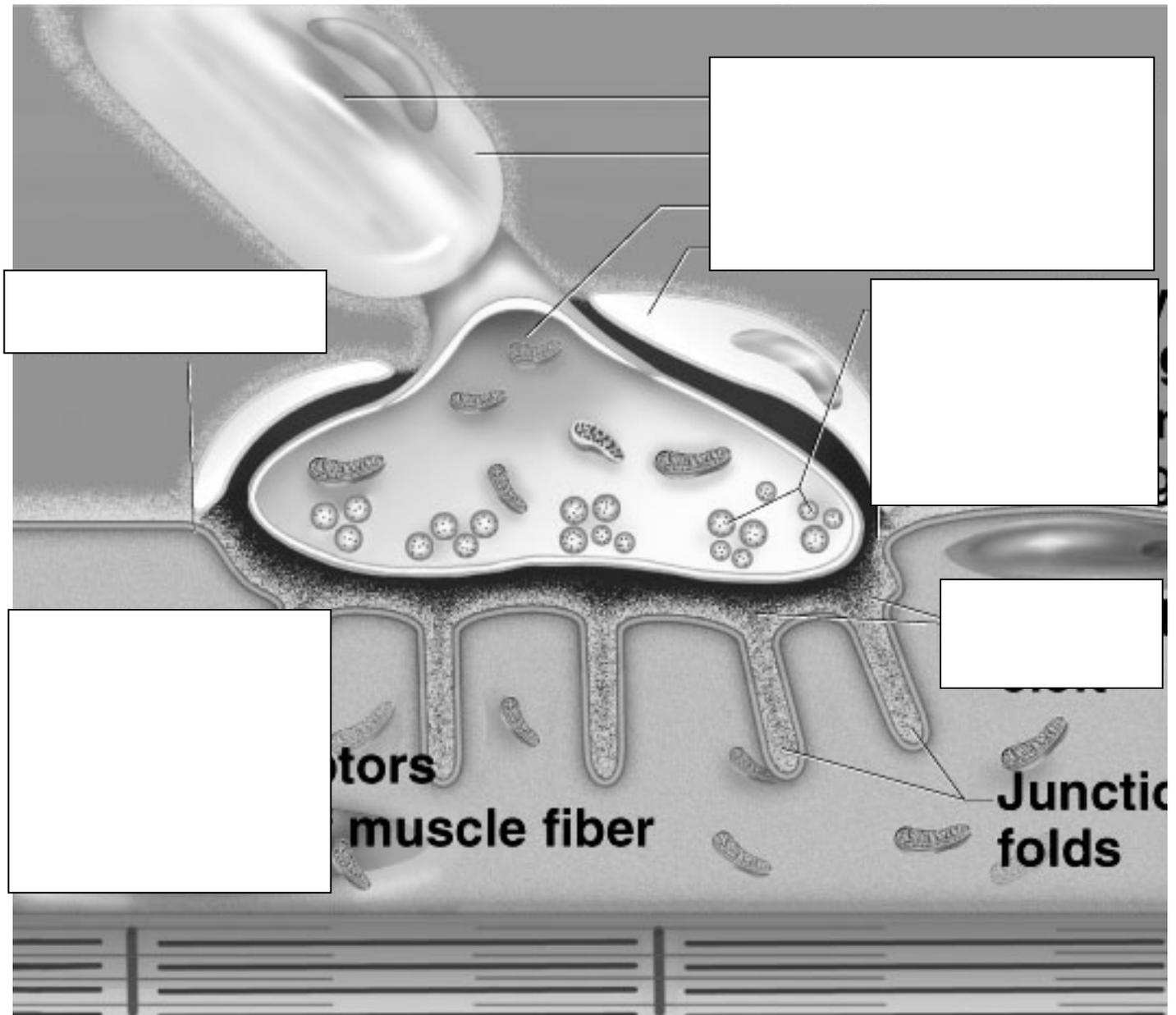
acetylcholinesterase

III. Workshop Activities

Activity A. The neuromuscular junction.

When a nerve cell connects to another cell, the connection is called a synapse (more about these in the next module). If the nerve cell is connecting to a muscle cell, the synapse is called a neuromuscular junction.

1. Label the diagram to the right with the following terms: neuron, muscle fiber, myofibril, thick filament, thin filament, synaptic cleft, endplate, sarcolemma, acetylcholine, vesicle, acetylcholinesterase, acetylcholine receptors (if you can't see these in the picture...draw them in).
2. When a signal arrives at the nerve terminus, acetylcholine is released into the synaptic cleft from the vesicles where it was stored. What kind of transport is this?



Activity B. Muscle excitation.

Break into pairs. Turn to the drawing of the neuromuscular junction on the last page of this workshop module, and label the inside and outside of the muscle cell. Anything in bold print should be labeled on the drawing. Transverse (t) tubules are like chutes (tunnels) of plasma membrane that go from one side of the membrane to

the other. Label the **t-tubules**. The **sarcoplasmic reticulum** is a specialized endoplasmic reticulum that surrounds the t-tubules and the **myofibril**. Label this as well. Calcium (Ca^{++}) is most concentrated outside of the cell and in the sarcoplasmic reticulum. From the last workshop, you should know where Na^+ and K^+ concentrations are highest. Indicate where the Ca^{++} , Na^+ and K^+ concentrations are highest on the drawing. Like last time, use beans to represent the various ions (Ca^{++} , Na^+ and K^+) and explain each of the following steps to the others in your group with each person taking a turn at explaining. Make a legend so that you can remember which color bean represents which ion. Draw in the various ion channels as they are mentioned.

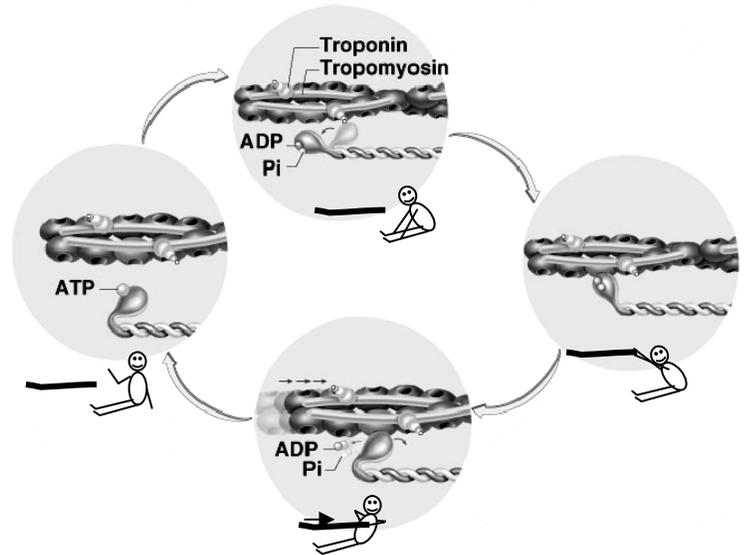
1. The nerve signal arrives and triggers **voltage-gated Ca^{++} channels** at the nerve terminus to open. Calcium travels down its electrochemical gradient into the neuron.
2. This triggers exocytosis of **synaptic vesicles** containing **acetylcholine (ACh)**.
3. ACh diffuses across the synapse and binds to **ACh receptors** on the sarcolemma. These receptors are also **ligand-gated channels** that allow Na^+ to enter the cell when ACh binds to the receptor. This causes the membrane potential (which was -90 millivolts at “rest”) to become positive ($+75\text{mV}$).
4. Like we saw in the last module, the positive charge inside the cell (depolarization) triggers K^+ to leave the cell (it wants to go out anyway because of the concentration gradient, but it really doesn’t like to be in the cell when all of the other positive ions are there). Thus the membrane potential returns to a value close to the resting membrane potential. In the neuromuscular junction, this quick depolarization-repolarization is called the **end-plate potential**.
5. Before the membrane potential is able to return to its resting state, the positive charge inside the cell causes **voltage-gated Na^+ channels** located on the sarcolemma near the end plate to open and allow even more Na^+ to come in. This makes the membrane potential more positive which triggers other nearby **Na^+ channels** to open which makes it more positive and so on. In this manner, the signal spreads along the sarcolemma. This is called an **action potential**. The action potential spreads along the sarcolemma and into the t-tubules, which allow the signal to spread to deeper parts of the cell quickly.
6. When the action potential reaches the t-tubules, the depolarization of the membrane potential triggers another kind of **voltage-gated Na^+ channel** to open. This channel on the t-tubule membrane is extraordinarily close to **voltage-gated Ca^{++} channels** in the nearby sarcoplasmic reticulum, so they both essentially open at the same time.
7. Ca^{++} stored in the sarcoplasmic reticulum then travels down its concentration gradient into the cytosol. Once in the cytosol, Ca^{++} binds to **troponin** (in the **troponin-tropomyosin** complex which is situated on top of the **actin** of the thin filament). This causes the tropomyosin to move so that the active sites on the thin filament are exposed.
8. Meanwhile, the positive charge inside the cell (depolarization) triggers K^+ to leave the cell. Thus the membrane potential returns to a value close to the resting membrane potential.

Activity C. The Sliding Filament Theory

As a group, act out contraction in the sarcomere. Assign people to the following roles: thick filament, thin filament, z-disc, tropomyosin, troponin. You may use props or people for the role of calcium, ATP, and anything else that you think of to build the skit. Make sure that you can demonstrate the steps of contraction and relaxation (when the sarcomere returns to its resting length).

Activity D. Close-up on muscle contraction.

Using your textbook and the figure to the right, write out the steps involved in each cycle of myosin-actin binding in your own words. Try acting it out using the stick figures as a guide. Pay attention to ATP and ADP + P_i (free phosphate).



Activity D. Follow up and extra help.

You should look at the CD-ROM that comes with your book to see more animations on the topic, but you can also do an internet search for helpful sites. Try going to google.com and searching for “sliding filament theory animation” and see what you come up with. If you find anything really helpful, I’d love to hear about it! Also, below are some sites that I found that I think are pretty cool. I particularly like the first one.

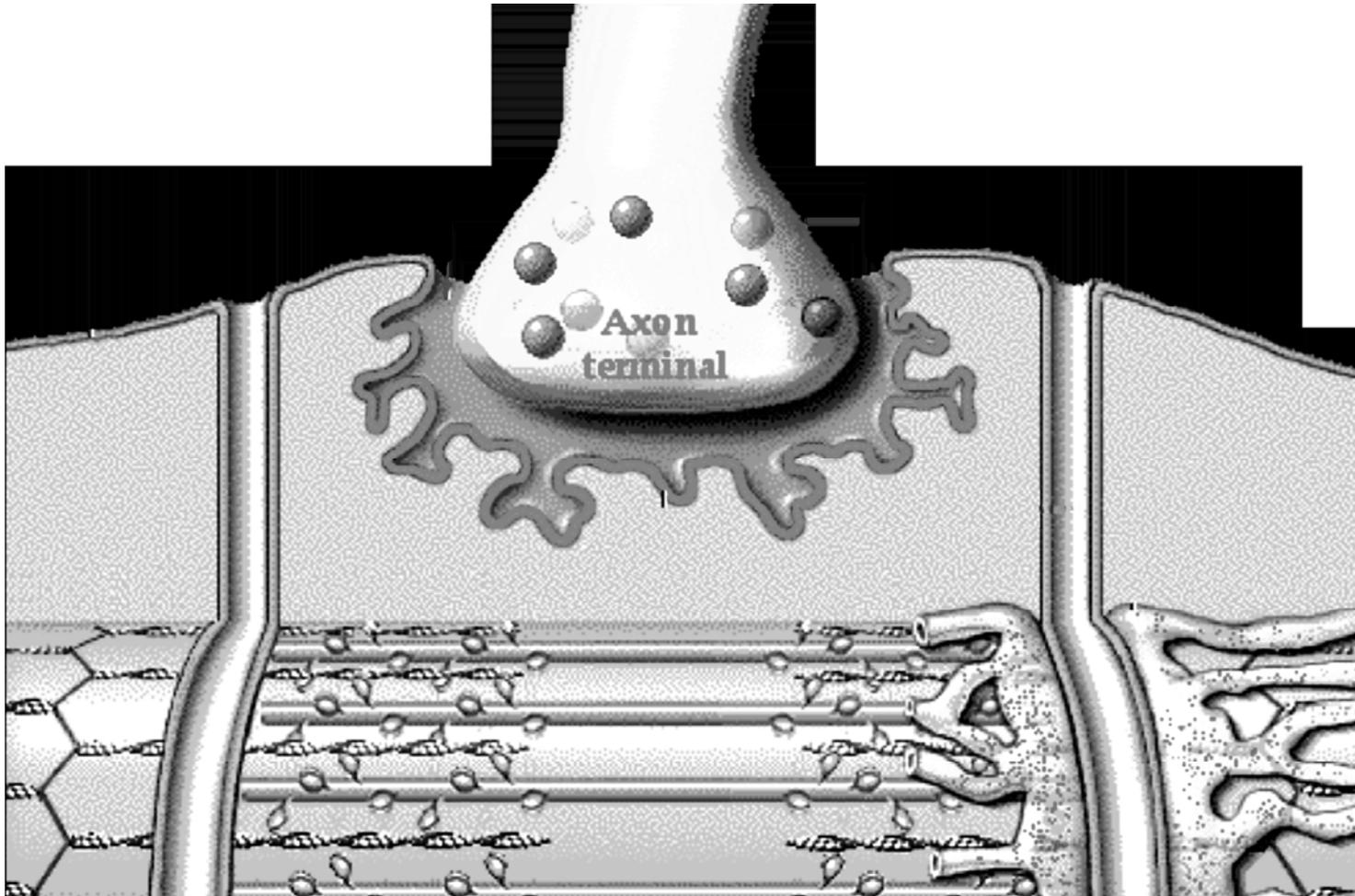
<http://www.blackwellscience.com/matthews/myosin.html>

<http://3dotstudio.com/zz.html>

<http://www.cartage.org.lb/en/themes/Sciences/LifeScience/GeneralBiology/Physiology/Muscular/SkeletalMuscle/SkeletalMuscle.htm>

This one’s pretty advanced, but you might take a look at it anyway...

http://www.zoology.ubc.ca/~auld/bio350/lectures/skeletal_muscle.html



Cite this module as: McDaniel, N. (2012). Peer-Led Team Learning Anatomy & Physiology, Module 9: Muscle Excitation and Contraction. Online at <http://www.pltlls.org>.

Originally published in *Progressions: The Peer-Led Team Learning Project Newsletter*, Volume 7, Number 3, Spring 2006.