Muscle Contraction Classroom Activity

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Description:
In this activity, students play the roles of the molecules involved in excitation-contraction coupling. It begins with release of ACh by a motor neuron and ends with release of Ca^{2+} from the sarcoplasmic reticulum. I use this activity after discussing the process in class and showing a brief animation.

Objectives:
After completing this activity, students will be able to describe the process of excitation contraction coupling and explain the role of the signals, molecules, ions, and transport proteins involved.

Preparation:
1) Use tape or long strips of paper to make a section of a muscle fiber on the floor of the classroom, hallway, or other large space. Indicate the sarcolemma, T-tubule, sarcoplamic reticulum, and myofibrils/sarcomere. I put the sarcolemma at the back of my classroom with the T-tubules extending forward along the center aisle and the space between the rows of tables indicated as the sarcoplasmic reticulum. The sacromere is my table in the front. I use 2 lines of tape about 8 inches apart to represent the bilayer membrane.

2) Write or print cards/name tags to identify roles of the students. I print them on 3x5 cards. the number can vary depending on the size of the class. I've used as few as 15 students (I play a role when necessary) and as many as 24 (more ions and transporters for bigger groups). I start with:

- 1 Neuron
- 1 Acetylcholine
- 1 Ach Receptor
- 2-4 Na^+
- 2-4 K^+
- 1-3 Voltage-Gated Na^+/K^+ Channels
- 1 Voltage-Gated Calcium Channel
- 1 Ryanodine Receptor
- 1-2 Ca^{2+}
- 1 Calcium pump
- 1 Na^+/K^+ ATPase Pump
- 1 Acetylcholinesterase

Part I – Setting the stage:
Hand out the cards to assign each student a role and identify the parts of the muscle fiber indicated by the tape or paper strips. Ask the students a series of questions to identify the roles and starting positions of each student:

1) How do signals from the plasma membrane get deep into the cell?

 T tubules (identify T-tubule)

2) What are the bundles of actin and myosin that contract?

 myofibrils/sacromeres (identify myofibril/sarcomeres)

3) What ion activates contraction of the sarcomeres?

calcium (find calcium)

4) Where does the calcium come from? Where is it when the muscle is not contracting?

sarcoplasmic reticulum (identify sarcoplasmic reticulum)

5) Ions like calcium can't cross the membrane without help. How did it get there?

calcium pump (place calcium pump at SR, have it move calcium into SR)

6) How does the calcium get out when it's time to contract?

ryanodine receptor, a calcium channel (place ryanodine receptor at SR)

7) Is the ryanodine receptor channel always open? What opens it?

no, linked to voltage gated channels in T-tubule (place voltage gates calcium channels)

8) What opens the voltage-gated calcium channels?

change in membrane potential

9) What causes the change in membrane potential that opens the channels?

Na^+ coming in and K^+ going out of the cell (find Na^+ and K^+)

10) How does the Na get out and K get in to start with?

Na^+/K^+ ATPase (place Na/K ATPase in sarcolemma, have it move Na^+/K^+)

11) What opened the channels that allowed Na^+ in and K^+ out all over the cell?

change in membrane potential (place voltage-gated ion channel)

12) What causes the depolarization that opens the voltage-gated channels?

Na^+ coming in the cell through Ach receptor channels

(place Ach receptor in the plasma membrane)

13) What opens the ligand-gated channels?

acetylcholine (find ACh)

14) Where does the Ach come from?

motor neuron (place neuron outside sacrolemma, place ACh at neuron)

Part II – Excitation-Contraction Coupling:

Prompt the students as necessary by asking them what will happen next and have them physically move to act out their part (for example, closed channels can stand parallel to the membrane to block movement across and open by turning sideways to usher ions across).

1) The motor neuron releases Ach.

(neuron directs the ACh toward ACh receptor)

2) Ach binds Ach receptors on the sarcolemma.

(ACh touches ACh receptor)

3) The Ach receptor opens and a little Na+ goes into the cell.

(ACh receptor moves a Na+ across sarcolemma)

4) This changes in membrane potential and opens nearby voltage-gated Na+/K+ channels so more Na+ goes in, K+ goes out.

(voltage-gated Na+/K+ channels move Na+ in and K+ out)

5) This action potential spreads alone the sarcolemma and down the T-tubules to open voltage-gated Ca^{2+} channels.

(voltage-gated Ca^{2+} channel moves a little)

6) The movement of the voltage-gated Ca^{2+} channel opens the ryanodine receptor channel.

(ryanodine receptor moves to open a path for Ca^{2+} out of the SR)

7) Ca^{2+} flows out of of the sarcoplasmic reticulum to the sarcomere
   (Ca^{2+} runs to the sarcomere)
8) The muscle contracts!

Part III – Relaxation:
Muscles don't contract forever so there has to be a way to stop the contraction and return everything to the resting state. Have the students reset the simulation with these steps.
1) The neuron stops signaling.
2) Acetylcholinesterase breaks down Ach.
   (Acetylcholinesterase moves ACh off the receptor)
3) Na+/K+ ATPase pumps moves Na+ out and K+ in.
   (ATPase moves Na+ and K+)
4) Voltage-gated channels close.
   (voltage-gated and ryanodine receptor channels close)
5) Ca^{2+} pump moves calcium back into SR.
   (Ca^{2+} pump moves Ca^{2+} back into SR)
6) Contraction stops.

Part IV – Repetition:
Typically, students need a lot of direction to get through the simulation the first time. I like to have the students run through parts II and III again without direction, having each student announce to the class what they are doing for each step. I let the students correct or prompt each other at this stage. If there is time, I collect and redistribute the cards so the students run it through a third time with new roles.

Extending the Activity:
The activity can be extended to reinforce other concepts or to test predictions.
1) Include troponin, tropomyosin, actin, and myosin to show that calcium binds to troponin to move the tropomyosin off the actin active sites so myosin can bind.
2) Stress the importance of each component in the process by removing one and asking the students what would happen. For example, what would happen if there was a defective Ca^{2+} pump? Or, how would muscle contraction be affected is acetylcholinesterase was not produced in adequate amounts? Have the students try to run the simulation without the missing component to see where the process stalls.
3) Simulate the action of drugs like muscle relaxants or toxins that affect the ion channels or receptors.