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**Discipline of Physiology**

Assignment Coversheet – Video Tutorial

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**Assignment Details**

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| --- | --- | --- | --- | --- | --- |
| Assignment Title | | **Script** | | | |
| Assignment number (if applicable) | |  | | | |
| Unit of Study Code (e.g. HSBH1006) | | **PHSI2905** | | | |
| Unit of Study Name | | **Integrated Physiology A** | | | |
| Unit of Study Coordinator or Tutor | | **Haydn Allbutt and Atomu Sawatari** | | | |
| Group or Tutorial ID: | | **4** | | | |
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**THE SKELETAL MUSCLE CONTRACTION CYCLE**

by BROOKE CAO, WEBER LIU, LUCINA MARTIN and SITA PALING

SIXTH DRAFT

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**1: TITLE**

“The Skeletal Muscle Contraction Cycle” will be presented as white words on a black background in Times New Roman font while the initial 6 seconds of “Spy Glass” by Kevin Macleod plays as background music.

a

**2: TYPES OF MUSCLE**

Very wide shot of an individual walking in the distance.

NARRATOR (V/O)

Skeletal muscle is attached to our bones, and it allows for voluntary body movement,

Dolly shot of individual walking and then bending their legs to squat.

NARRATOR (V/O) (CONT’D)

Such as flexing,

Freeze for 2 seconds while individual is squatted then unfreeze to show individual standing up straight again and walking again.

NARRATOR (V/O) (CONT’D)

And extension of limbs. Skeletal muscle is made of myofibrils, of which the smallest contractile unit is the sarcomere.

Zoom out and then Continue dolly shot of walking individual for 5 seconds

**3: OVERVIEW OF SKELETAL MUSCLE CONTRACTION**

Fade to cardboard models of actin and myosin laid on white background.

NARRATOR (V/O)

In this tutorial we look into the composition of sarcomeres and the sliding filament theory, which describes how skeletal muscles contract at a molecular level. It involves the binding of myosin,

Draw blue circle around the myosin and manually move the head so it binds to actin.

NARRATOR (V/O)(CONT’D)

And the microfilament, actin.

Fade off circle around myosin and draw blue circle around actin.

NARRATOR (V/O)(CONT’D)

The conformational change of myosin,

Manually move the filaments to perform a powerstroke.

NARRATOR (V/O)(CONT’D)

The release of the actin,

Manually detach the myosin head from the actin.

NARRATOR (V/O) (CONT’D)

The recovery stroke,

Manually perform recovery stroke of myosin head.

NARRATOR (V/O) (CONT’D)

And the repetition of this process.

Repeat the manual movements of the myosin molecule to show the contraction cycle.

Fade to large flow diagram that consists of images of all four steps, labelled, and in a circle, joined by arrows. While Kevin Macleod’s “Spy Glass” plays in the background, zoom in on step 1, labelled “Crossbridge formation,” then pan to step 2, “Powerstroke,” then step 3, “Detachment,” and finally step 4, “Recovery stroke.” Zoom back out to show full diagram.

**4: INTRO TO COMPONENTS OF THE SARCOMERE**

Fade to close up of all the cardboard cut-outs of each element of the sarcomere, including the troponin, actin, tropomyosin, myosin, titin and nebulin, sitting on a white table.

NARRATOR (V/O)

Firstly, let's have a look at the components of the sarcomere which are involved in the sliding filament theory.

Move all of the cut-outs off screen and place the actin polymer in the centre of the shot.

NARRATOR (V/O) (CONT’D)

Here we have actin also known as the 'thin filament'. It contains many myosin binding sites along each monomer in its structure.

Overlay type on screen “THIN FILAMENT” in black, Times New Roman font. Fade off “THIN FILAMENT”. Move the actin cut-out off screen place the myosin cut-out in the centre of the shot.

NARRATOR (V/O) (CONT’D)

And here, is Myosin.

Fade to cardboard cut-out of myosin molecule on white table.

NARRATOR (V/O)(CONT’D)

It has two globular heads, each containing an ATPase, which hydrolyses ATP to ADP and inorganic phosphate. Myosin uses the chemical energy contained in ATP to do mechanical work.

Zoom in on myosin head and draw circle around the ATPase. Move a cardboard molecule of ATP towards the head and then switch out the ATP cut-out with the ADP and Pi cut-out.

NARRATOR (V/O)(CONT’D)

The globular heads also have an actin-binding site. This site has a strong affinity for the myosin-binding site on the actin polymer.

Remove ADP and Pi. Draw circle around the actin-binding site.

NARRATOR (V/O)(CONT’D)

Bundles of myosin form the thick filament of the sarcomere.

Zoom out to show whole myosin molecule then zoom in on myosin tail. Add numerous more myosin tails to the diagram and overlay type on screen “THICK FILAMENT” in black Times New Roman font. Fade off “THICK FILAMENT”, zoom out to show whole myosin molecule.

NARRATOR (V/O)(CONT’D)

This is tropomyosin, a regulatory protein. It covers the myosin binding sites on actin when the muscle fibre is at rest.

Move myosin into view, with the head cocked, unattached (but close) to yellow actin binding regions, because of the tropomyosin covering all of the yellow binding regions \*pause\* Add troponin cut-out to the diagram and zoom in on troponin, bound to actin and tropomyosin.

NARRATOR (V/O)(CONT’D)

This is troponin, which is attached to tropomyosin and actin. It contains a binding sites for calcium ions. It is common to confuse tropomyosin with troponin, so, an easy way to remember is…

Type text ‘Tropo**myosin** regulates **myosin** ’ overlaid on screen in black Times New Roman.

NARRATOR (V/O)(CONT’D)

Tropomyosin regulates myosin’s attachment to actin. Troponin on the other hand has direct regulatory contact with tropomyosin but not myosin. Hence…

Fade to ‘**Tropo**nin regulates **tropo**myosin’ overlaid on screen in black Times New Roman font. Leave text for 3 seconds before fading text off screen.

NARRATOR (V/O) (CONT’D)

Now that we are familiar with the contractile filaments, we can answer our crucial question: How does muscle contraction occur?

**5: STEP 1 OF CONTRACTION CYCLE - CROSSBRIDGE FORMATION**

Underneath the video, a small white progress bar divided into four sections (labelled in black text with each step of cycle) will appear. As we progress through the steps the bar will fill in blue.

Fade to large flow diagram of the full cycle. Zoom in on Step 1, “Crossbridge formation”, while Kevin Macleod’s “Spy Glass” plays in the background, for 5 seconds. Fade to cardboard cut-out diagram of myosin, actin, tropomyosin and troponin on white table.

NARRATOR (V/O)

Let’s start with the myosin molecule in its cocked state, with ADP and inorganic phosphate bound to the head. At this stage it contains potential energy, much like a stretched rubber band.

Cut to close-up of a rubber band being stretched. Cut back to cardboard cut-out diagram on white table.

NARRATOR (V/O)(CONT’D)

As there is tropomyosin blocking the myosin binding sites on actin, the affinity between the two polymers is reduced and so they form a very weak cross-bridge.

Point (with hand) to tropomyosin blocking binding sites.

NARRATOR (V/O)(CONT’D)

When a motor nerve has been fired, calcium ions flood into the sarcoplasm. They bind to troponin, which causes conformational changes in tropomyosin, so that the binding sites on actin are now exposed.

Introduce cardboard cut-out of calcium ion to the diagram, move it to bind with troponin and then move tropomyosin to expose binding sits on actin.

NARRATOR (V/O) (CONT’D)

This drastically increases the affinity between the actin and myosin molecules, hence, the weak crossbridges become much stronger.

Move myosin head closer to touch actin binding site.

**6: STEP 2 OF CONTRACTION CYCLE – POWERSTROKE**

Fade to large flow diagram of the full cycle. Zoom in on Step 2, “Powerstroke”, while Kevin Macleod’s “Spy Glass” plays in the background, for 5 seconds. Fade to cardboard cut-out diagram of myosin, actin, tropomyosin and troponin on white table.

NARRATOR (V/O)

When the strong crossbridge is formed, a phosphate ion is released.

Remove the inorganic phosphate cut-out from the myosin head.

NARRATOR (V/O)(CONT’D)

This in turn causes a conformational change in the myosin molecule, so the head swivels from about a 90-degree angle to 45 degrees. Hence, the potential energy stored in the myosin molecule is converted into kinetic energy.

Cut to release of the stretched rubber band.

NARRATOR (V/O)(CONT’D)

This motion is called the powerstroke. The myosin remains tightly bound to actin, so that the actin filaments are moved towards the centre of the sarcomere.

Cut back to Cardboard cut-out diagram. Move the myosin head while it is attached to actin to demonstrate the powerstroke motion.

NARRATOR (V/O) (CONT’D)

Macroscopically, this is observed as a shortening of skeletal muscle, or muscle contraction.

Cut to close up shot of individual’s bicep as they lift a weight.

NARRATOR (V/O)(CONT’D)

The ADP is released at the end of the powerstroke but the myosin head remains bound to the actin filament.

Cut back to cardboard cutout diagram. Remove the ADP from the myosin head.

**7: STEP 3 OF CONTRACTION CYCLE - DETACHMENT**

Fade to large flow diagram of the full cycle. Zoom in on Step 3, “Detachment”, while Kevin Macleod’s “Spy Glass” plays in the background, for 5 seconds. Fade to cardboard cut-out diagram of myosin, actin, tropomyosin and troponin on white table.

NARRATOR (V/O)

The sarcomere is now in rigor conformation. Observed externally, this muscle fibre will appear to be contracted.

Cut to close up shot of individual’s contracted bicep. After 2 seconds cut back to cardboard cutout diagram.

NARRATOR (V/O) (CONT’D)

ATP now has a high affinity for its binding site on myosin, and when it binds, a conformational change of myosin is induced, which reduces the affinity of the myosin head to the actin filament. Thus, the myosin head detaches from actin.

Introduce ATP cardboard cut-out molecule to the diagram and attach it to the myosin head, before detaching the myosin head from the actin.

NARRATOR (V/O) (CONT’D)

During this time, an ATP-driven Calcium ion pump is rapidly removing calcium ions from the sarcoplasm. This means that, if there is not another nerve signal resulting in another influx of calcium, the tropomyosin will once again cover the myosin-binding sites on the actin molecule.

Remove calcium from troponin and place the tropomyosin over the myosin-binding sites.

**8: STEP 4 OF CONTRACTION CYCLE - RECOVERY STROKE**

Fade to large flow diagram of the full cycle. Zoom in on Step 4, “Recovery stroke”, while Kevin Macleod’s “Spy Glass” plays in the background, for 5 seconds. Fade to cardboard cut-out diagram of myosin, actin, tropomyosin and troponin on white table.

NARRATOR (V/O)

But how does myosin prepare for its next powerstroke? A series of conformational changes in the myosin molecule couple the activation of its ATPase function with the movement of the head back to its original, pre-power stroke position.

Manually move the myosin head through the recovery stroke motion.

NARRATOR (V/O) (CONT’D)

This repriming of the myosin head is called the recovery stroke,

Overlay type text “RECOVERY STROKE” on screen in black Times New Roman font. After 3 seconds fade off text.

NARRATOR (V/O) (CONT’D)

And it is coupled with ATP hydrolysis.

Manually replace ATP with ADP and Pi.

NARRATOR (V/O) (CONT’D)

The products of ATP hydrolysis, ADP and Pi, remain bound to myosin, forming a metastable complex.

Zoom in on ADP and Pi bound to myosin head.

NARRATOR (V/O) (CONT’D)

And there we have it! The cycle is completed. The myosin head is now primed to form a weak crossbridge with the actin filaments, ready to start the cycle all over again.

**9: CONCLUSION**

Zoom into the progress bar at the bottom of the screen and animate it to form a circle.

NARRATOR (V/O)

Let’s have one last look at our contraction cycle in summary.

Fade on overall flow diagram of the contraction cycle while Kevin Macleod’s “Spy Glass” is playing in the background, for 5 seconds.

NARRATOR (V/O)(CONT’D)

At rest, with no calcium present, myosin and actin form a weak cross-bridge. The myosin binding sites on actin are blocked by tropomyosin. A nerve signal eventually leads to an influx of calcium ions into the sarcoplasm. There bind to troponin, causing a conformational change in tropomyosin. Thereby, the myosin-binding sites on the actin filament become exposed. This allows for strong binding between the myosin head and actin, which in turn induces the power stroke. During the power stroke, the inorganic phosphate ion and ADP are released. At this point, if no ATP is available, the myosin remains bound to the actin filament, in the 'rigor state'. However, when an ATP molecule binds to the myosin head, myosin and actin lose their strong affinity and detach. Finally, myosin performs the recovery stroke and ATP hydrolysis, so it is in its original conformation once again.

Point (with hand) to each step and component of the diagram as it is mentioned.

NARRATOR (V/O)(CONT’D)

An easy way to remember these 4 steps is ‘Can People Die Rockclimbing?’

Fade on black Times New Roman text “CAN PEOPLE DIE ROCKCLIMBING?” overlaid on a background picture of a rock climbing wall.

NARRATOR (V/O)(CONT’D)

Crossbridge formation,

Fade black Times New Roman text onto white background “Can” (with emphasis on the C by typing it in a bigger font and bold).

NARRATOR (V/O)(CONT’D)

Powerstroke,

Fade off “Can” and fade on “People” (with emphasis on the P by typing it in a bigger font and bold).

NARRATOR (V/O)(CONT’D)

Detachment,

Fade off “People” and fade on “Die” (with emphasis on the D by typing it in a bigger font and bold).

NARRATOR (V/O)(CONT’D)

Recovery stroke.

Fade off “Die” and fade on “Rockclimbing” (with emphasis on the R by typing it in a bigger font and bold).

NARRATOR (V/O)(CONT’D)

Now let’s try a question to test your understanding. Consider a situation where the myosin heads have just performed a powerstroke, but there is no ATP available. What would happen?

Fade on multiple choice options in black text on white

background.

“a.      The myosin heads would detach from actin

b.      The recovery stroke would occur whilst the myosin is still attached to actin

c.      The myosin heads would remain bound to actin, but the muscle fibre would relax

d.      The myosin heads would remain bound to actin but the muscle fibre would remain contracted”

Remain on this screen for 15 seconds.

NARRATOR (V/O)(CONT’D)

Explanation: (a) is incorrect because the myosin heads won’t detach from actin without ATP binding.

Draw red line through option (a) on the screen.

NARRATOR (V/O)(CONT’D)

(b) is incorrect because the recovery stroke cannot be performed while myosin is still bound to actin.

Draw red line through option (b) on the screen.

NARRATOR (V/O)(CONT’D)

(c) is incorrect because if the recovery stroke is not performed, the muscle fibre cannot relax.

Draw red line through option c) on the screen.

NARRATOR (V/O)(CONT’D)

And therefore, (d) is correct! This is the rigor state we mentioned earlier. When this occurs in a dead body it is called rigor mortis.

Draw large red tick next to option (d) on screen. Fade to wide shot of individual climbing up a rockclimbing wall.

NARRATOR (V/O)(CONT’D)

So, if all else fails, just ask yourself, Can People Die Rockclimbing?

Fade on black Times New Roman text “Can People Die Rockclimbing?” overlaid on wide shot of individual rockclimbing. Play Kevin Macleod’s “Spy Glass” for 5 seconds.

**10: CREDITS**

Cut to black Times New Roman text on white background:

“‘The Skeletal Muscle Contraction Cycle’ by Weber Liu, Lucina Martin, Brooke Cao and Sita Paling.

References:

Boundless Biology 2016, *Sliding Filament Model of Contraction*, Boundless, viewed 10 April 2016, https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the-musculoskeletal-system-38/muscle-contraction-and-locomotion-218/sliding-filament-model-of-contraction-825-12068

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Mansson, A., Rassier, D., Tsiavaliaris, G. 2015, ‘Poorly understood aspects of striated muscle contraction’, *BioMed Research International*, vol. 2015, article ID 245154, 28 pages.

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"Spy Glass" Kevin MacLeod (incompetech.com)Licensed under Creative Commons: By Attribution 3.0 License http://creativecommons.org/licenses/by/3.0/“

Play Kevin Macleod’s “Spy Glass” in the background for 10 seconds.