Muscle Types

Subject & topics: Biology | Physiology | Sense & Movement **Stage & difficulty:** A Level P3

There are three main types of muscle tissue in vertebrates:

- Skeletal muscle
- Cardiac muscle
- Smooth muscle

The three types of muscle tissue differ in both their structure and function.

Part A

Functions

Match the type of muscle to the location(s) and function in the table below.

Type of muscle	Location	Function
	heart	contracts to pump blood out of the heart
	multiple internal organs (e.g. stomach, intestines, bladder, uterus) and blood vessels	contracts to move contents along/out of the organ/vessel
	attached to bones	contracts to enable movement of the body

Items:

skeletal cardiac smooth

Part B

Skeletal muscle

Which of the following statements apply to **skeletal** muscle tissue? Select all that apply.

- [ ] Each fibre consists of a single cell with a single nucleus.
- [ ] Each fibre consists of multiple cells fused together, and therefore contains multiple nuclei.
- [ ] Fibres are arranged in parallel lines and **do not** form connections/branches between different lines.
- [ ] Fibres are arranged in parallel lines and **do** form connections/branches between different lines.
- [ ] Fibres show no ordered arrangement and **do not** form branches.
- [ ] Fibres are striated (i.e. striped in appearance) due to the presence of sarcomeres.
- [ ] Fibres are non-striated (i.e. are not striped in appearance) due to the absence of sarcomeres.

Part C

Cardiac muscle

Which of the following statements apply to **cardiac** muscle tissue? Select all that apply.

- [ ] Each fibre consists of a single cell with a single nucleus.
- [ ] Each fibre consists of multiple cells fused together, and therefore contains multiple nuclei.
- [ ] Fibres are arranged in parallel lines and **do not** form connections/branches between different lines.
- [ ] Fibres are arranged in parallel lines and **do** form connections/branches between different lines.
- [ ] Fibres show no ordered arrangement and **do not** form branches.
- [ ] Fibres are striated (i.e. striped in appearance) due to the presence of sarcomeres.
- [ ] Fibres are non-striated (i.e. are not striped in appearance) due to the absence of sarcomeres.

Part D

Smooth muscle

Which of the following statements apply to **smooth** muscle tissue? Select all that apply.

- Each fibre consists of a single cell with a single nucleus.
- Each fibre consists of multiple cells fused together, and therefore contains multiple nuclei.
- Fibres are arranged in parallel lines and **do not** form connections/branches between different lines.
- Fibres are arranged in parallel lines and **do** form connections/branches between different lines.
- Fibres show no ordered arrangement and **do not** form branches.
- Fibres are striated (i.e. striped in appearance) due to the presence of sarcomeres.
- Fibres are non-striated (i.e. are not striped in appearance) due to the absence of sarcomeres.

Sarcomere Structure

Subject & topics: Biology | Physiology | Sense & Movement **Stage & difficulty:** A Level P3

Striated muscle (i.e. skeletal muscle and cardiac muscle) is striated in appearance due to the presence of sarcomeres. A diagram of a sarcomere is shown below.

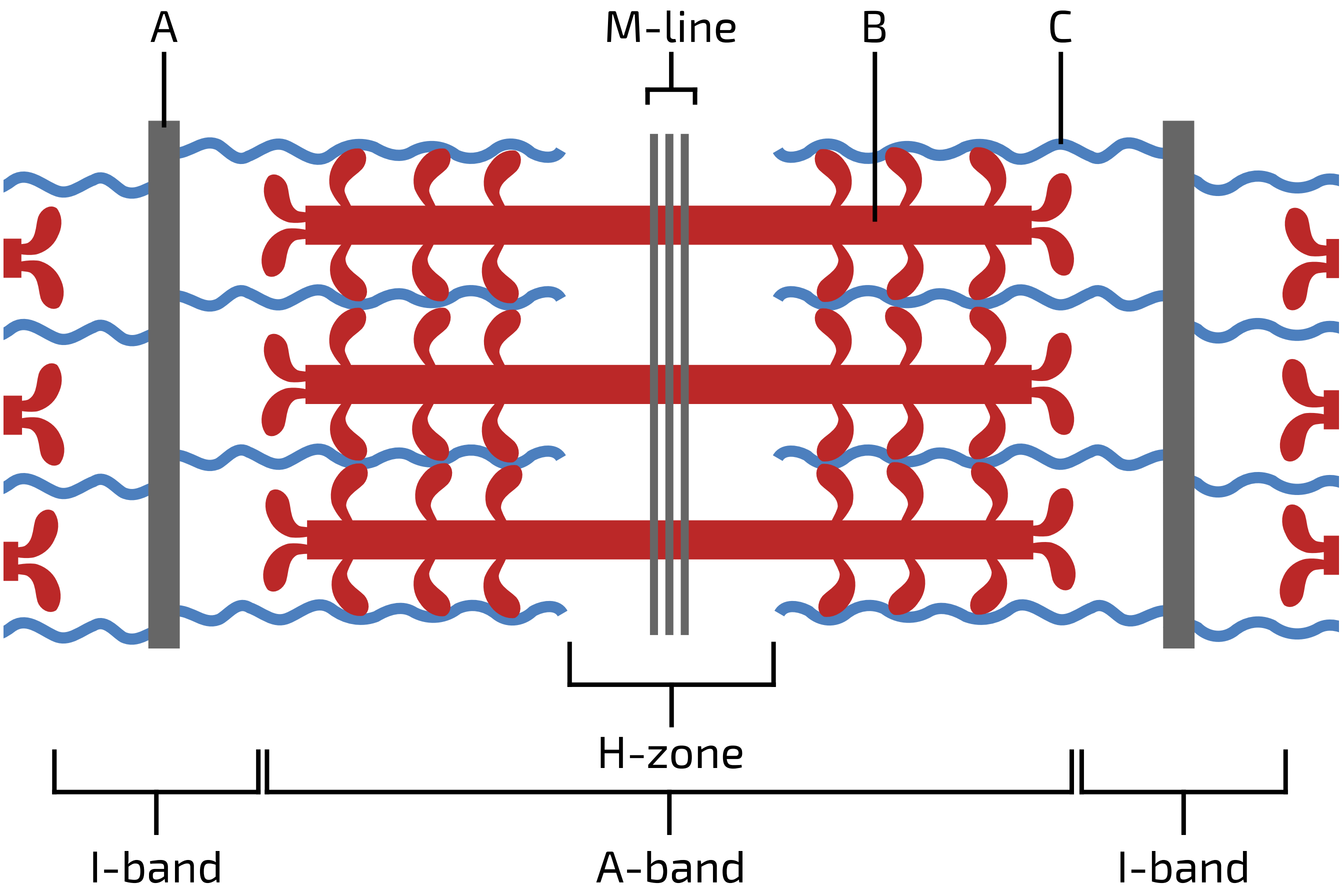

Figure 1: Diagram of a sarcomere. At the top of the diagram, components of the sarcomere are labelled. At the bottom of the diagram, regions of the sarcomere are labelled. These regions are defined by the presence or absence of components B and C. The H-zone contains only component B. The A-band (also called the dark band) contains both. The I-band (also called the light band) contains only component C. A sarcomere includes everything from component A (on the left) to the same component on the right. A single I-band, therefore, straddles two adjacent sarcomeres.

Part A
Component A

Give the name of component A in **Figure 1**.

Part B
Component B

Give the name of the molecule that makes up component B in **Figure 1**.

Part C
Component C

Give the name of the molecule that makes up component C in **Figure 1**.

Part D

Muscle contraction

Which of the following components/regions in **Figure 1** become shorter when the muscle contracts?

- [ ] Component **A**
- [ ] M-line
- [ ] Component **B**
- [ ] Component **C**
- [ ] H-zone
- [ ] I-band
- [ ] A-band

Part E

Muscle structure

Drag the items below into the correct order on the right to show the levels of skeletal muscle structure from largest (top) to smallest (bottom).

Available items

- myofibril
- muscle fibre (myocyte/myofibre/muscle cell)
- muscle
- sarcomere

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Neuromuscular Junctions

Subject & topics: Biology | Physiology | Sense & Movement **Stage & difficulty:** A Level P3

A neuromuscular junction is a synapse between a motor neurone and a muscle fibre. There are many similarities between neuronal synapses and neuromuscular junctions, but there are also some differences.

Part A

Neuromuscular junction transmission

Drag the items below into the correct order on the right to show how a motor neurone triggers muscle contraction at a neuromuscular junction.

Available items

- Ca^{2+} ions in the sarcoplasm allow myosin to bind to (and pull) actin in the sarcomeres, causing muscle contraction
- an action potential is propagated along the axon of a motor neurone
- voltage-gated Ca^{2+} channels in the membrane of the sarcoplasmic reticulum open and Ca^{2+} ions move out into the sarcoplasm
- neurotransmitters are released into the synaptic cleft
- the membrane of the axon terminal is depolarised
- vesicles containing neurotransmitters fuse with the axon terminal membrane
- voltage-gated Ca^{2+} channels in the membrane of the axon terminal open and Ca^{2+} ions move in
- Na^{+} channels on the sarcolemma open and Na^{+} ions move in
- neurotransmitters bind to Na^{+} channels on the sarcolemma

Part B

Neurotransmitter name

What is the name of the neurotransmitter that is used in vertebrate neuromuscular junctions?

Part C

Neuromuscular junctions vs neuronal synapses

Which of the following are differences between neuromuscular junctions and chemical neuronal synapses in vertebrates? Select all that apply.

- [ ] Neuromuscular junctions only use acetylcholine as a neurotransmitter whereas neuronal synapses use a range of neurotransmitters (including acetylcholine).
- [ ] At a neuromuscular junction, the concentration of Ca^{2+} ions increases in the cytoplasm of the postsynaptic cell. This does not happen at a neuronal synapse.
- [ ] Neuromuscular junctions use acetylcholine as a neurotransmitter whereas neuronal synapses do not use acetylcholine as a neurotransmitter.
- [ ] At a neuronal synapse, the concentration of Na^{+} ions increases in the cytoplasm of the postsynaptic cell. This does not happen at a neuromuscular junction.
- [ ] At a neuromuscular junction, transmission is always excitatory whereas at a neuronal synapse, transmission can be excitatory or inhibitory.
- [ ] A neuromuscular junction is a synapse between a neurone and a muscle fibre whereas a neuronal synapse is a synapse between a neurone and another neurone.

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Sliding Filament Theory

Subject & topics: Biology | Physiology | Sense & Movement **Stage & difficulty:** A Level P3

The mechanism by which skeletal muscle contraction works is explained by the sliding filament theory/model. This theory proposes that muscle contraction works by thin filaments (composed of actin) sliding along thick filaments (composed of myosin) to contract the sarcomeres that make up the myofibrils.

In a muscle at rest, myosin cannot pull actin towards the centre of the sarcomere because two other molecules are bound to actin filaments: tropomyosin and troponin. The release of Ca^{2+} ions from the sarcoplasmic reticulum (triggered by a nerve impulse from a motor neurone) causes these molecules to detach from actin filaments, allowing myosin to bind and pull the actin towards the centre.

Part A

Sequence of events

Drag the items below into the correct order on the right to show how skeletal muscle contraction works, beginning with Ca^{2+} ion release.

Available items

- Each "cocked" myosin head (bound to ADP and inorganic phosphate (P_i)) binds to a myosin-binding site on the actin filament.
- A new molecule of ATP binds to each myosin head, detaching it from the myosin-binding site it was attached to.
- Ca^{2+} ions bind to troponin. Troponin undergoes a conformational change, which moves tropomyosin away from the myosin-binding sites on the actin filament.
- Ca^{2+} ions are released from the sarcoplasmic reticulum into the sarcoplasm in response to a nerve impulse from a motor neurone.
- Myosin-bound ATP is then hydrolysed to ADP and inorganic phosphate (P_i) and the previous three steps can repeat, provided the concentration of Ca^{2+} ions remains high enough for myosin-bind sites to remain "open".
- ADP and inorganic phosphate (P_i) are released from the myosin heads, causing the myosin heads to return from their "cocked" position to their "relaxed" position, thus pulling actin towards the centre of the sarcomere.

Part B

Muscle relaxation

Which of the following processes occur in a muscle during its relaxation?

- [ ] the Z-lines of each sarcomere move **closer together**
- [ ] the Z-lines of each sarcomere move **further apart**
- [ ] the H-zone (central region of the sarcomere in which there is only myosin and no actin) becomes **shorter**
- [ ] the H-zone (central region of the sarcomere in which there is only myosin and no actin) becomes **longer**
- [ ] the I-bands (regions around the Z-lines in which there is only actin and no myosin) become **shorter**
- [ ] the I-bands (regions around the Z-lines in which there is only actin and no myosin) become **longer**

Part C

Rigor mortis

Dead bodies undergo a process called "rigor mortis" a few hours after death, during which the body stiffens due to the muscles contracting and not relaxing. This process lasts for several hours.

Explain why this occurs (choose one statement that explains why muscles contract, and one statement that explains why they do not relax).

- [ ] Contraction: the motor neurones start to produce action potentials
- [ ] Contraction: the sarcoplasmic reticulum breaks down, releasing its Ca^{2+} ions into the sarcoplasm.
- [ ] Contraction: actin and myosin break down
- [ ] Lack of relaxation: the mitochondria are no longer producing ATP, so the myosin remains bound to the actin after contraction
- [ ] Lack of relaxation: the motor neurones keep producing action potentials for the duration of rigor mortis
- [ ] Lack of relaxation: the sarcoplasmic reticulum keeps releasing Ca^{2+} ions into the sarcoplasm for the duration of rigor mortis

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Reflex Arcs

Subject & topics: Biology | Physiology | Sense & Movement **Stage & difficulty:** A Level P3

Part A

Fill in the blanks

A reflex arc is a pathway of [ ] involved in producing a specific reflex action (a rapid, [ ] muscle response to a stimulus).

A reflex arc may be monosynaptic (i.e. only involving one synapse between one sensory neurone and one [ ]) or polysynaptic (i.e. involving one or more [ ]s).

Items:

involuntary | muscles | voluntary | hormones | neurones | relay neurone | motor neurone

Part B

Reflex sequence

Drag the items below into the correct order on the right to show how a reflex action is produced in a polysynaptic reflex arc.

Available items

- the impulse is transmitted across a synapse to a relay neurone
- a stimulus is detected by a sensory receptor
- the muscle contracts
- the impulse is transmitted across a neuromuscular junction to a muscle
- an impulse travels along the sensory neurone
- an impulse travels along the relay neurone
- the impulse is transmitted across a synapse to a motor neurone
- an impulse travels along the motor neurone
- Ca^{2+} ions are released by the sarcoplasmic reticulum into the sarcoplasm of the muscle fibres

Part C

Reflex examples

Which of the following are examples of reflex actions (i.e. actions produced by reflex arcs)? Select all that apply.

- [ ] an individual rapidly moving their hand away from something very hot
- [ ] the dilation/constriction of the pupil in response to a change in light intensity
- [ ] an individual kicking their leg out in response to something hitting the tendon beneath their kneecap
- [ ] the contraction of throat muscles in response to something touching the back of the individual's throat
- [ ] an individual covering their ears with theirs hands in response to a loud noise
- [ ] an individual releasing more ADH in response to a decrease in their blood water potential
- [ ] the contraction of the left ventricle in response to a signal from the Purkyne fibres
- [ ] an individual blinking in response to something touching the cornea of their eye

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STEM SMART Biology Week 39 - The Muscular System

Muscle Energy Expenditure

Subject & topics: Biology | Physiology | Sense & Movement **Stage & difficulty:** A Level C3, Further A C1

This question involves using ***moles*** *, which is part of GCSE and A Level Chemistry. For more information please check with your teacher.*

Muscle cells primarily use glycogen to provide the energy they need. Glycogen is broken down into glucose, which is used in respiration to produce ATP.

An individual ("individual A") undergoes $30\,\mathrm{minutes}$ of high-intensity exercise. During this exercise, their muscles break down, on average, $1.5\,\mathrm{g}$ of stored glycogen per minute.

Part A

ATP calculation

How many molecules of ATP did individual A's muscles produce during this period of exercise?

Assume that:

- an average molecule of glycogen is composed of $30,000$ glucose molecules
- each molecule of glucose produces 30 ATP molecules during aerobic respiration
- all of the glucose molecules that are produced are aerobically respired
- the muscles are only using stored glycogen to produce ATP

Give your answer to 1 significant figure.

Part B

ATP functions

Which of the following processes will ATP be directly used for in the muscle cells of individual A during the period of exercise? Select all that apply.

- [ ] binding to myosin heads to enable detachment from actin
- [ ] binding to actin to enable detachment from Z-lines
- [ ] phosphorylating myosin heads
- [ ] active transport of Ca^{2+} ions **into** the sarcoplasmic reticulum
- [ ] active transport of Ca^{2+} ions **out of** the sarcoplasmic reticulum in response to the influx of Na^{+} ions
- [ ] active transport of Na^{+} ions **into** the cell in response to acetylcholine
- [ ] active transport of Na^{+} ions **out** of the cell
- [ ] active transport of K^{+} ions **into** the cell