Physics. You work it out.

Home Gameboard Biology Physiology Sense & Movement Nervous System Organisation

Nervous System Organisation

A Level
P P P

The vertebrate nervous system can be categorised into different subsystems, based on structure and/or function.

Part A Levels of organisation

Complete the table below to show the organisation of the vertebrate nervous system.

<table>
<tr><td rowspan="4">nervous system</td><td>central
nervous system</td><td colspan="2"></td></tr>
<tr><td rowspan="3">____ nervous system</td><td>____ nervous system</td><td></td></tr>
<tr><td rowspan="2">____ nervous system</td><td>sympathetic
nervous system</td></tr>
<tr><td>____ nervous system</td></tr>
</table>

Items:

peripheral parasympathetic autonomic somatic

Part B Nervous subsystem descriptions

Match the nervous subsystem to the description in the table below.

Description	Nervous subsystem
the brain and spinal cord	
all of the neurones that connect the central nervous system to other organs/tissues	
the parts of the nervous system that are under **subconscious** control	
the parts of the nervous system that are under **conscious** control	
the parts of the autonomic nervous system that are involved in triggering a "fight-or-flight" response	
the parts of the autonomic nervous system that are involved in "rest & digest" functions	

Items:

sympathetic nervous system **somatic nervous system** **parasympathetic nervous system**

peripheral nervous system (PNS) **central nervous system (CNS)** **autonomic nervous system**

Part C Somatic nervous system

Which of the following actions/behaviours are mainly controlled by the **somatic** nervous system? Select all that apply.

- [ ] typing on a keyboard
- [ ] stomach peristalsis
- [ ] pupil dilation
- [ ] blinking
- [ ] dancing
- [ ] producing saliva

Part D Autonomic nervous system

Which of the following actions/behaviours are mainly controlled by the **autonomic** nervous system? Select all that apply.

- [ ] running away from a predator
- [ ] breathing
- [ ] sweating
- [ ] decreasing heart rate
- [ ] chewing food
- [ ] increasing heart rate

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Physics. You work it out.

Home Gameboard Biology Physiology Sense & Movement Neurone Structure

Neurone Structure

A Level
P P P

Neurones are highly specialised cells with a unique structure. The various parts of a neurone carry out different roles in the overall function of the neurone.

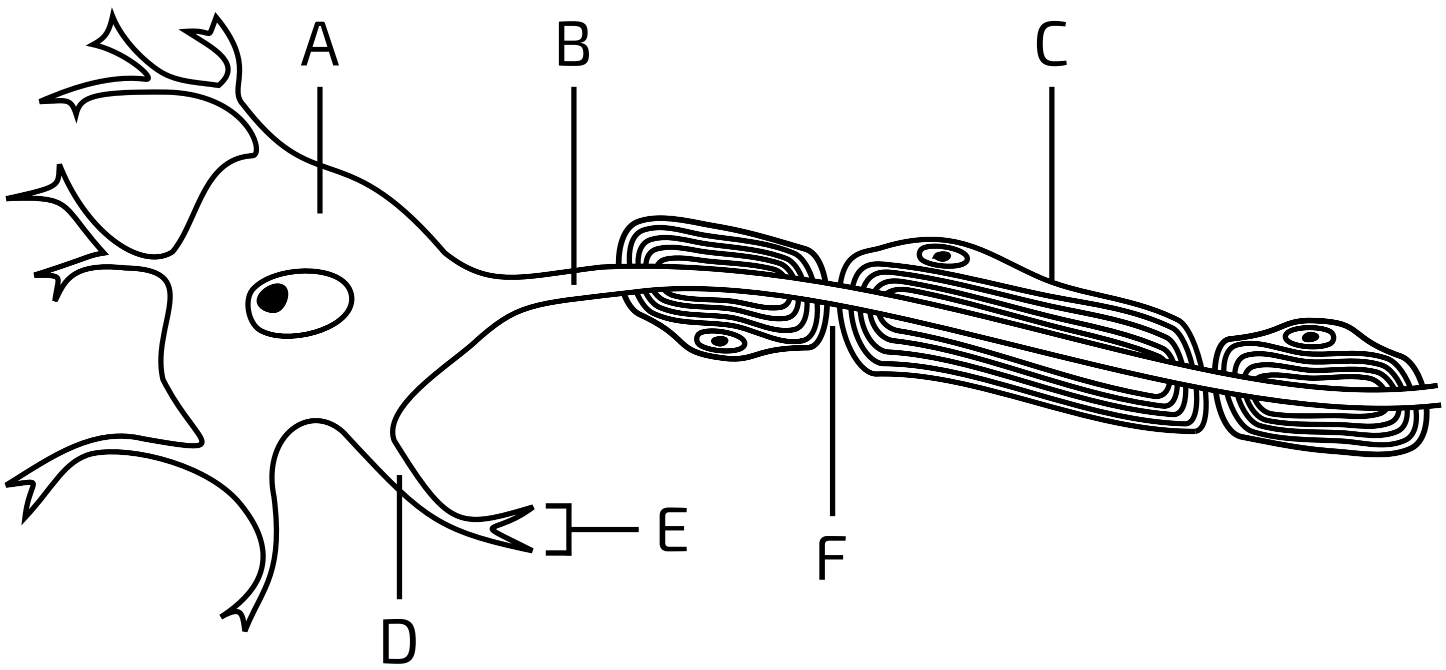

Figure 1: Part of a motor neurone.

Part A Label the neurone

Match the letter in **Figure 1** to the region/structure in the table below.

Letter	Region/structure
A	
B	
C	
D	
E	
F	

Items:

myelin sheath **dendron** **node of Ranvier** **dendrites** **axon** **cell body (soma)**

Part B Myelin

Which of the following statements about myelin are correct? Select all that apply.

- [ ] myelin increases the speed of an impulse along a neurone by being a strong conductor of electricity
- [ ] myelin increases the speed of an impulse along a neurone by preventing ion movement across the neurone membrane at that point
- [ ] a myelin sheath is composed of extra layers of the neurone's own membrane that are deposited at a specific point along the axon/dendron
- [ ] a myelin sheath is composed of layers of another cell's membrane that are wrapped around a specific point of the axon/dendron of a neurone
- [ ] myelin in the peripheral nervous system (PNS) is formed by Schwann cells
- [ ] all neurones are myelinated

Part C Synapse at E

Which of the following cell types could form a synapse with the neurone at region **E** in **Figure 1**? Select all that apply.

- muscle cell
- gland cell
- sensory neurone
- motor neurone
- relay neurone

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STEM SMART Biology Week 39 - The Nervous System

Neurone Types

A Level

P P P

There are many different types of neurones, but most can be grouped into one of three main categories: motor neurones, sensory neurones, and relay neurones (interneurons).

Part A Types & functions

Match the type of neurone to the function in the table below.

Neurone type	Function
	(also called afferent neurones) receive impulses from a sense organ (e.g. skin, eyes, etc.) and transmit them to one or more neurones
	(also called efferent neurones) receive impulses from one or more neurones and transmit them to a muscle or gland
	(also called interneurons) transmit impulses from one neurone to another

Items:

sensory neurones **motor neurones** **relay neurons**

Part B Characteristics

Match the neurone type(s) to the characteristic in the table below.

Characteristic	Neurone type(s)
is myelinated	
may form a synapse with a relay neurone	
cell body lies within the CNS	
dendron is usually longer than the axon	
cell body lies outside of the CNS	
has many dendrites	

Items:

motor neurones only **sensory neurones only** **both sensory and motor neurones**

Part C Sensory neurone examples

Which of the following are examples of **sensory** neurones? Select all that apply.

- olfactory receptor neurones (neurones in the nasal cavity that respond to odours and send an impulse towards the brain)
- photoreceptor cells e.g. rods and cones (neurones in the eye that respond to light and send impulses towards the brain)
- thermoreceptors (neurones in the skin and other organs/tissues that respond to changes in temperature and send impulses towards the CNS)
- neurones in the femoral nerve that send impulses from the spinal cord to the muscles in the thigh to cause the leg to straighten at the knee

Part D Motor neurone examples

Which of the following are examples of **motor** neurones? Select all that apply.

- mechanoreceptor neurones (neurones in the skin and other organs/tissues that respond to pressure/movement and send impulses towards the CNS)
- neurones in the oculomotor nerve that send impulses from the brain to muscles in the eye to cause eye movement
- neurones in the infundibulum that send impulses from the hypothalamus to the posterior pituitary gland to cause the release of hormones into the bloodstream
- retinal ganglion cells (neurons that receive impulses from photoreceptor cells and send impulses to neurons in the brain)

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Physics. You work it out.

Home Gameboard Biology Physiology Sense & Movement The Resting Membrane Potential

The Resting Membrane Potential

A Level C C C Further A C C C

The resting membrane potential is the membrane potential of a neuron when it is "at rest" i.e. not firing. The resting membrane potential of most neurones is approximately $-65\,\mathrm{mV}$ i.e. the inside of the cell is $65\,\mathrm{mV}$ more negative than the outside of the cell.

Part A The sodium-potassium pump

The $\mathrm{Na^+/K^+}$ pump (also called $\mathrm{Na^+/K^+}$-ATPase) plays an essential role in maintaining the membrane potential in all animal cells including neurones. Fill in the blanks below to explain how this works.

1. ____ molecule(s) of ATP binds to a $\mathrm{Na^+/K^+}$ pump.
2. This allows ____ $\mathrm{Na^+}$ ions to bind to the $\mathrm{Na^+/K^+}$ pump on the ____ of the membrane.
3. The ATP is converted to ADP and P_i, which phosphorylates the $\mathrm{Na^+/K^+}$ pump. This causes a conformational change in the shape of the $\mathrm{Na^+/K^+}$ pump.
4. This causes the $\mathrm{Na^+}$ ions to be released to the ____ of the membrane.
5. ____ $\mathrm{K^+}$ ions bind to the $\mathrm{Na^+/K^+}$ pump on the ____ of the membrane. This causes dephosphorylation of the $\mathrm{Na^+/K^+}$ pump, which causes a conformational change back to the original shape.
6. This causes the $\mathrm{K^+}$ ions to be released to the ____ of the membrane. The process is now ready to begin again.

Because this process results in a net loss of ____ charges from the cell, the inside of the cell becomes ____ly charged relative to the outside.

Items:

1 2 3 4 5 **inside** **outside** **positive** **negative**

Part B Ion leakage

On its own, the $\mathrm{Na^+}$/$\mathrm{K^+}$ pump would result in the cell becoming increasingly negative until there were no more $\mathrm{Na^+}$ ions inside the cell. However, this is not the case. There are some ion channels that allow $\mathrm{Na^+}$ to leak into the cell, and other ion channels that allow $\mathrm{K^+}$ ions to leak out of the cell.

What is the name given to this kind of transport, in which ions move through channels down/with their concentration gradient?

Part C $\mathrm{K^+}$ equilibrium potential

On its own, the concentration gradient of $\mathrm{K^+}$ ions would cause them to leak out of the cell. However, the outside of the cell is more positively charged than the inside of the cell, which will counteract this movement of $\mathrm{K^+}$ ions. The movement of ions across a membrane is, therefore, based on **both** the chemical gradient **and** the electrical potential across the membrane. The electrical potential for which these two things balance out (for a particular ion) is called the equilibrium potential. At the equilibrium potential, the net movement of that ion across the membrane through its ion channel will be zero.

The Nernst equation can be used to calculate the equilibrium potential (E) in millivolts (mV) for a particular ion (X) given its valency (z), concentration inside the cell ($[X]_\mathrm{i}$), and concentration outside the cell ($[X]_o$). The equation is as follows:

$$E_X = \frac{61}{z} \times \log_{10} \frac{[X]_o}{[X]_\mathrm{i}}$$

Use the Nernst equation (above) to calculate the equilibrium potential for $\mathrm{K^+}$ ions ($E_{\mathrm{K^+}}$) when:

- $\mathrm{K^+}$ concentration inside the cell ($[\mathrm{K^+}]_\mathrm{i}) = 120\,\mathrm{mM}$
- $\mathrm{K^+}$ concentration outside the cell ($[\mathrm{K^+}]_o) = 4\,\mathrm{mM}$

Give your answer to 2 significant figures.

Part D $\mathrm{Na^+}$ equilibrium potential

The Nernst equation can be used to calculate the equilibrium potential (E) in millivolts (mV) for a particular ion (X) given its valency (z), concentration inside the cell ($[X]_\mathrm{i}$), and concentration outside the cell ($[X]_o$). The equation is as follows:

$$E_X = \frac{61}{z} \times \log_{10} \frac{[X]_o}{[X]_\mathrm{i}}$$

Use the Nernst equation (above) to calculate the equilibrium potential for $\mathrm{Na^+}$ ions ($E_{\mathrm{Na^+}}$) when:

- $\mathrm{Na^+}$ concentration inside the cell ($[\mathrm{Na^+}]_\mathrm{i}) = 15\,\mathrm{mM}$
- $\mathrm{Na^+}$ concentration outside the cell ($[\mathrm{Na^+}]_o) = 145\,\mathrm{mM}$

Give your answer to 2 significant figures.

Part E Neurone resting membrane potential

The resting membrane potential of most neurones is $\approx -65\,\mathrm{mV}$. Based on your answers to the previous sections, which of the following conclusions can you draw? Select all that apply.

- [ ] The resting membrane potential is closer to the equilibrium potential of $\mathrm{K^+}$ than to the equilibrium potential of $\mathrm{Na^+}$
- [ ] The resting membrane potential is closer to the equilibrium potential of $\mathrm{Na^+}$ than to the equilibrium potential of $\mathrm{K^+}$
- [ ] There is more leakage of $\mathrm{K^+}$ ions across the neurone membrane than leakage of $\mathrm{Na^+}$ ions across the neurone membrane
- [ ] There is more leakage of $\mathrm{Na^+}$ ions across the neurone membrane than leakage of $\mathrm{K^+}$ ions across the neurone membrane
- [ ] There is the same amount of leakage of both types of ions across the neurone membrane

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Action Potentials

A Level
P P P

An action potential is a sequence of changes in membrane potential that occur at a particular point of a cell membrane in response to a stimulus. An action potential at one point of a cell membrane can trigger an action potential at a nearby point of a cell membrane. In neurones, this propagation of action potentials along the cell membrane is called a nerve impulse.

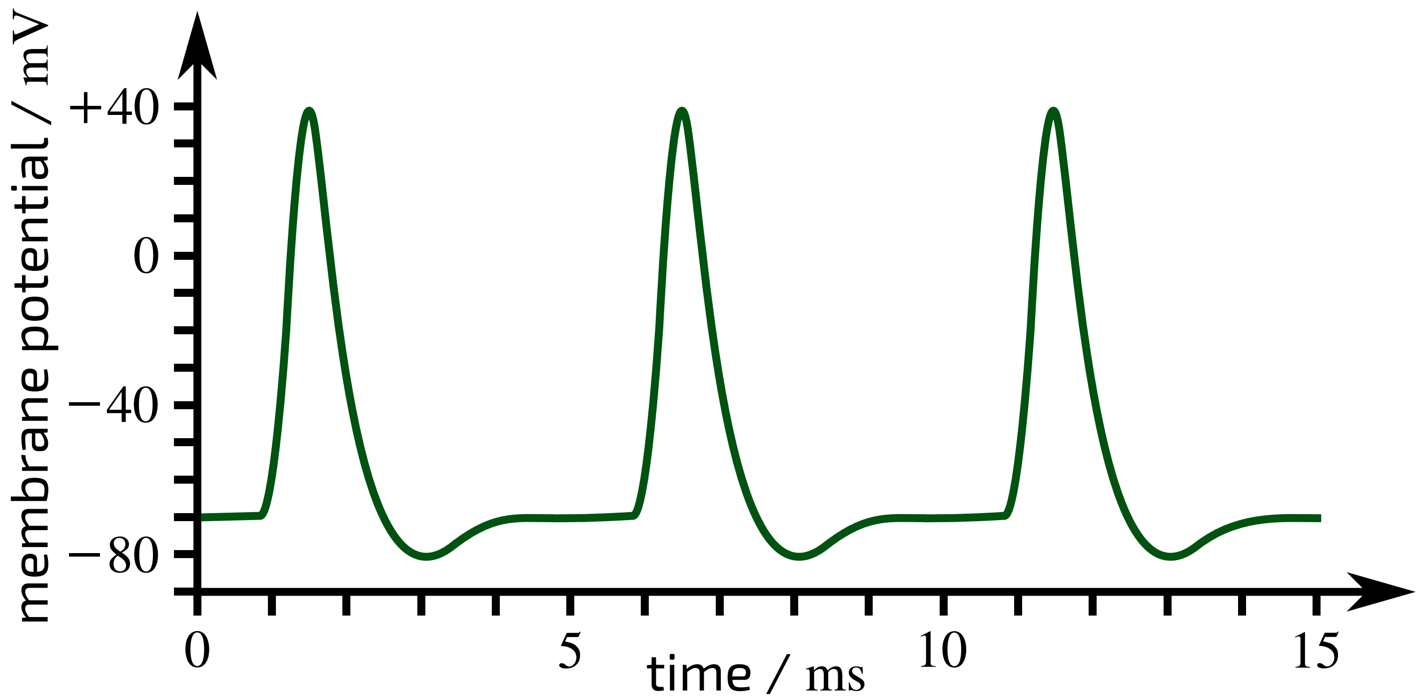

Figure 1: A series of action potentials. The membrane potential at a particular point of a cell membrane is shown over time.

Part A Resting membrane potential

State the value of the resting membrane potential in **Figure 1**

Part B Depolarisation

Which of the following events occur between 1 and 1.5 milliseconds in **Figure 1**?

Select all that apply.

- [ ] voltage-gated K^+ channels open
- [ ] voltage-gated Na^+ channels open
- [ ] K^+ ions flow **into** the cell through voltage-gated K^+ channels
- [ ] K^+ ions flow **out of** the cell through voltage-gated K^+ channels
- [ ] Na^+ ions flow **into** the cell through voltage-gated Na^+ channels
- [ ] Na^+ ions flow **out of** the cell through voltage-gated Na^+ channels

Part C Repolarisation & hyperpolarisation

Which of the following events occur between 1.5 and 4 milliseconds in **Figure 1**?

Select all that apply.

- [ ] voltage-gated K^+ channels **open**
- [ ] voltage-gated K^+ channels **close**
- [ ] voltage-gated Na^+ channels **open**
- [ ] voltage-gated Na^+ channels **close**
- [ ] K^+ ions flow **into** the cell through voltage-gated K^+ channels
- [ ] K^+ ions flow **out of** the cell through voltage-gated K^+ channels
- [ ] Na^+ ions flow **into** the cell through voltage-gated Na^+ channels
- [ ] Na^+ ions flow **out of** the cell through voltage-gated Na^+ channels

Adapted with permission from OCR A Level June 1999, Biology Foundation, Question 3

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STEM SMART Biology Week 39 - The Nervous System

Synapses

A Level
P P P

A synapse is the junction between two neurones (or between a neurone and an effector e.g. a muscle fibre or gland cell). There are two types of synapse: electrical and chemical. Electrical synapses involve the direct movement of ions from one cell to another. Chemical synapses involve the transmission of an impulse via chemical messengers (neurotransmitters). Electrical synapses can transmit impulses more quickly, but chemical synapses are more flexible in terms of processing the impulses. Because of this, chemical synapses are far more common than electrical synapses.

Part A Synaptic transmission

Drag the items below into the correct order on the right to show how one neurone excites another neurone at a chemical synapse.

Available items

- Na^{+} channels on the membrane of the postsynaptic neurone open and Na^{+} ions move in
- the membrane of the axon terminal is depolarised
- neurotransmitters bind to Na^{+} channels on the membrane of the postsynaptic neurone
- an action potential is triggered in the postsynaptic neurone and propagates along its dendron/axon
- neurotransmitters are released into the synaptic cleft
- an action potential is propagated along the axon of a presynaptic neurone
- 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

Part B Synapse statements

Which of the following statements are correct? Select all that apply.

- neurotransmitters are released by simple diffusion
- neurotransmitters are released by exocytosis
- neurotransmitters can only excite neurones (i.e. trigger an action potential), they cannot inhibit them (i.e. prevent an action potential)
- some neurotransmitters excite neurones (i.e. trigger an action potential) while others inhibit neurones (i.e. prevent an action potential)
- a postsynaptic neurone might require multiple action potentials in a short space of time from the same presynaptic neurone in order for it to produce its own action potential
- a postsynaptic neurone might require multiple, simultaneous action potentials from several presynaptic neurones in order for it to produce its own action potential

Part C Electrical vs chemical synapses

In electrical synapses, the two neurones are physically connected by membrane protein channels that allow ions to move directly from the cytoplasm of one cell to the next. In chemical synapses, the two neurones are not physically connected to each other. The impulse in the presynaptic neurone triggers a release of neurotransmitters which can then trigger an impulse in the postsynaptic neurone.

What are the advantages of a chemical synapse over an electrical synapse? Select all that apply.

- chemical synapses can transmit impulses much faster than electrical synapses
- chemical synapses can be used for excitation or inhibition, whereas electrical synapses can only be used for excitation
- chemical synapses allow impulse movement in both directions, whereas electrical synapses only allow an impulse to move in one direction
- chemical synapses don't require ion channels, whereas electrical synapses do
- chemical synapses can be altered more easily to change the strength of transmission

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