PSY.BIO2 Neurons and Synaptic Transmission

Total Marks

AQA 7182 · Calculators not allowed · about 40 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Diagram A shows a typical multipolar neuron. Label the three structures A, B and C on the diagram: A is the structure that receives incoming signals from other neurons; B is the long fibre that carries the action potential away from the cell body; C is the fatty layer that speeds up transmission along the axon.

Label the neuron diagram: name A, B and C with one-word labels.

(Total for Question 1 is 3 marks)

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2 Diagram B shows a chemical synapse between two neurons. Label the three parts X, Y and Z where: X is where neurotransmitter molecules are stored inside the presynaptic ending; Y is the space neurotransmitters cross; Z is where neurotransmitters bind on the postsynaptic neuron.

Label the synapse diagram: name X, Y and Z with single-term labels.

(Total for Question 2 is 3 marks)

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3 State the function of terminal buttons at the end of an axon in chemical synaptic transmission, in one sentence and in the context of neurotransmitter release.

(Total for Question 3 is 2 marks)

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4 Outline one structural difference between sensory (afferent) neurons and motor (efferent) neurons, and explain how that difference relates to their function in carrying information.

(Total for Question 4 is 4 marks)

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5 Explain what is meant by an excitatory postsynaptic potential (EPSP) and an inhibitory postsynaptic potential (IPSP), and give one named neurotransmitter commonly associated with excitation and one commonly associated with inhibition in the brain.

(Total for Question 5 is 3 marks)

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6 State two roles of the myelin sheath on an axon and explain briefly how each role affects the speed or reliability of neural transmission.

(Total for Question 6 is 4 marks)

7 Identify the type of neuron that typically has its cell body located in a dorsal root ganglion and carries information from peripheral receptors to the CNS, naming the neuron type and giving one structural feature that distinguishes it.

(Total for Question 7 is 2 marks)

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8 Explain, in two or three sentences, how the arrival of an action potential at the presynaptic terminal leads to the release of neurotransmitter from synaptic vesicles.

(Total for Question 8 is 4 marks)

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9 State one way in which dopamine and serotonin can differ in their typical roles in the brain, giving a named role for each neurotransmitter.

(Total for Question 9 is 3 marks)

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10 Explain the process of receptor binding on the postsynaptic membrane and how this can produce either excitation or inhibition in the postsynaptic neuron.

(Total for Question 10 is 2 marks)

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11 Outline the concept of summation in the postsynaptic neuron, distinguishing between temporal and spatial summation, and explain briefly why summation is important for action potential generation.

(Total for Question 11 is 4 marks)

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12 Describe the process of synaptic transmission from the arrival of an electrical impulse at the presynaptic terminal to the generation of a postsynaptic potential, and explain how this process can lead to either excitation or inhibition of the postsynaptic neuron. In your answer be selective and organised.

(Total for Question 12 is 6 marks)

Mark scheme · PSY.BIO2 Neurons and Synaptic Transmission

Question 1

- **B1** A labelled as dendrites cao
- **B1** B labelled as axon cao
- **B1** C labelled as myelin sheath cao
- **Answer: A = dendrites. B = axon. C = myelin sheath.**

Question 2

- **B1** X labelled as synaptic vesicles cao
- **B1** Y labelled as synaptic cleft cao
- **B1** Z labelled as receptor sites or receptors cao
- **Answer: X = synaptic vesicles. Y = synaptic cleft. Z = receptor sites (receptors).**

Question 3

- **B1** states that terminal buttons release neurotransmitter into the synaptic cleft when an action potential arrives cao
- **B1** or states that terminal buttons contain synaptic vesicles which fuse with the membrane to release chemical messengers cao
- **Answer: Terminal buttons contain synaptic vesicles and release neurotransmitter into the synaptic cleft when an action potential arrives.**

Question 4

- **M1** identifies a genuine structural difference, e.g. sensory neurons often have receptor endings and a long peripheral axon or a cell body in a dorsal root ganglion, whereas motor neurons have a cell body in the CNS and multiple dendrites oe
- **A1** explains how this relates to function: sensory neuron structure transmits sensory information from receptors towards the CNS, while motor neuron structure sends signals from the CNS to effectors such as muscle oe
- **M1** alternative structural difference: sensory neurons can be unipolar/has peripheral process, motor neurons are multipolar with many dendrites oe
- **A1** explains functional consequence of the alternative point, e.g. many dendrites allow motor neurons to integrate multiple inputs before triggering muscle contraction oe
- **Answer: E.g. sensory neurons often have receptor endings and a peripheral process that carries signals into the CNS, whereas motor neurons have their cell body in the CNS and many dendrites with a long axon out to muscle; this suits sensory neurons for transmitting receptor information in and motor neurons for sending commands out.**

Question 5

- **M1** defines EPSP as a small depolarisation of the postsynaptic membrane that makes the neuron more likely to fire an action potential oe
- **M1** defines IPSP as a small hyperpolarisation that makes the postsynaptic neuron less likely to fire oe
- **A1** gives one named neurotransmitter associated with excitation (e.g. acetylcholine or glutamate) and one associated with inhibition (e.g. GABA or serotonin in some pathways) cao
- **Answer: EPSP: a small depolarisation making firing more likely; IPSP: a small hyperpolarisation making firing less likely. Example neurotransmitters: acetylcholine or glutamate for excitation; GABA for inhibition.**

Question 6

- **M1** states one role: electrical insulation of the axon oe
- **A1** explains that insulation prevents ion leakage and maintains the strength of the action potential, improving reliability of transmission oe
- **M1** states second role: enabling saltatory conduction so impulses jump between nodes of Ranvier oe
- **A1** explains that saltatory conduction increases conduction velocity, so signals travel faster along myelinated axons oe
- **Answer: Roles: electrical insulation, which reduces ion leakage and helps maintain signal integrity; and enabling saltatory conduction, where impulses jump between nodes of Ranvier to increase conduction speed.**

Question 7

- **B1** identifies the neuron as a sensory (afferent) neuron cao
- **B1** gives a distinguishing structural feature, e.g. a unipolar/pseudo-unipolar shape or having a peripheral process and a central process with the cell body off to one side oe
- **Answer: Sensory (afferent) neuron. Distinguishing feature: often pseudo-unipolar with a peripheral process from the receptor and a central process into the CNS, with the cell body in a dorsal root ganglion.**

Question 8

- **M1** explains that arrival of the action potential opens voltage-gated calcium channels in the presynaptic membrane oe
- **A1** explains that Ca2+ influx causes synaptic vesicles to fuse with the presynaptic membrane and release neurotransmitter into the synaptic cleft via exocytosis oe
- **M1** may mention vesicle docking and fusion proteins or the role of calcium in triggering release oe
- **A1** links the process to the chemical transmission across the synapse oe
- **Answer: When an action potential arrives it opens voltage-gated calcium channels; Ca2+ enters the terminal and triggers synaptic vesicles to fuse with the presynaptic membrane, releasing neurotransmitter into the synaptic cleft by exocytosis.**

Question 9

- **M1** states a role for dopamine, e.g. involved in reward, motivation and motor control oe
- **M1** states a role for serotonin, e.g. involved in mood regulation, appetite and sleep oe
- **A1** makes the contrast explicit, e.g. dopamine often linked to reward/motor function while serotonin is often linked to mood regulation oe
- **Answer: Dopamine: commonly associated with reward, motivation and motor control. Serotonin: commonly associated with mood regulation, appetite and sleep; dopamine is more linked to reward and motor function while serotonin is more linked to mood.**

Question 10

- **M1** explains that neurotransmitter molecules bind to specific receptor sites causing ion channels to open or close oe
- **A1** explains that opening channels that admit Na+ causes depolarisation (EPSP) whereas opening channels that admit Cl- or K+ causes hyperpolarisation (IPSP) oe
- **Answer: Neurotransmitter binds to specific postsynaptic receptors, causing ion channels to open or close; if channels open for Na+ this depolarises the membrane producing an EPSP, whereas opening channels for Cl- or K+ hyperpolarises the membrane producing an IPSP.**

Question 11

- **M1** defines summation as the combining of multiple EPSPs and IPSPs at the axon hillock oe
- **A1** explains temporal summation as successive impulses from a single presynaptic neuron building up to reach threshold oe
- **M1** explains spatial summation as simultaneous inputs from several presynaptic neurons combining their effects oe
- **A1** explains why important: summation determines whether threshold is reached so an action potential will or will not be generated oe
- **Answer: Summation is the combining of EPSPs and IPSPs at the axon hillock; temporal summation is rapid successive inputs from one presynaptic cell adding together, spatial summation is simultaneous inputs from many presynaptic cells adding together, and summation is crucial because it determines whether the threshold for an action potential is reached.**

Question 12

- **Level 3** (5-6): Detailed, accurate and well organised description of synaptic transmission. Key steps are clearly explained in sequence, including arrival of the action potential, Ca2+ entry, vesicle fusion and neurotransmitter release, diffusion across the cleft, receptor binding and ion channel actions. Explanation includes how receptor action produces EPSPs or IPSPs and a clear account of how excitation or inhibition results. Specialist terms used correctly.
- **Level 2** (3-4): Clear description of the main steps of synaptic transmission with some detail. Most key processes are described, for example vesicle release and receptor binding, but explanation of how excitation or inhibition arises may be incomplete or less well developed. Organisation is adequate and terminology mostly correct.
- **Level 1** (1-2): Limited description, missing several key steps or showing some inaccuracies. May mention neurotransmitter release or receptor binding but lacks clear sequence or explanation of excitation versus inhibition. Little organisation and limited technical vocabulary.
- **Level 0** (0): No relevant content.
- **Indicative content:**
  - Action potential arrives at presynaptic terminal and depolarises the membrane.
  - Voltage-gated calcium channels open, Ca2+ ions enter the presynaptic terminal.
  - Ca2+ influx triggers synaptic vesicles to move to and fuse with the presynaptic membrane, releasing neurotransmitter by exocytosis into the synaptic cleft.
  - Neurotransmitter molecules diffuse across the synaptic cleft to the postsynaptic membrane.
  - Neurotransmitter binds to specific receptor proteins on the postsynaptic membrane, causing ion channels to open or close.
  - If receptor activation opens Na+ channels this produces an EPSP (depolarisation); if it opens K+ channels or Cl- channels this produces an IPSP (hyperpolarisation).
  - Summation of EPSPs and IPSPs at the axon hillock determines whether the postsynaptic neuron reaches threshold and fires an action potential.
  - Named neurotransmitters may be included: e.g. acetylcholine acting at neuromuscular junctions or central cholinergic synapses as excitatory, dopamine involved in modulatory/excitatory pathways, serotonin often modulates mood and can have inhibitory effects in some circuits, and GABA as a major inhibitory transmitter.
  - Mention of reuptake or enzymatic breakdown may be included as part of clearing neurotransmitter from the cleft and terminating the signal.