Unit 4 Practice FRQ 2022

1. Acetylcholine receptor (AChR) proteins are found at the synapse between neurons and skeletal muscle cells. Acetylcholine released from neurons binds to a specific site on the receptor proteins, which causes an ion channel in the receptors to open and allow sodium ions (Na^+) to enter muscle cells. The resulting depolarization of muscle cells initiates muscle contractions. Another molecule, nicotine, can also bind to certain types of AChR proteins and activate the receptors.

A researcher is investigating two different types of AChR proteins: type 1 and type 2. To determine which stimuli activate the receptors, the researcher exposes muscle cells expressing the different types of receptor proteins to stimuli and observes the results indicated in Table 1.

TABLE 1. RESPONSE OF AChR PROTEINS TO DIFFERENT STIMULI

AChR Protein Type	Acetylcholine	Nicotine
Type 1	+	+
Type 2	+	–

+ indicates activation
– indicates no activation

(a) **Describe** the difference in the structure AND function between AChR type 1 and AChR type 2.

Please respond on separate paper, following directions from your teacher.

(b) Acetylcholinesterase is an enzyme that breaks down acetylcholine in the synapse. **Describe** the effect of inhibiting acetylcholinesterase on the muscle cells with AChR type 2.

Please respond on separate paper, following directions from your teacher.

Part A

2 points maximum

Description (2 points)

Points may be earned from only one row.

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Structure (1 point maximum)	Function (1 point maximum)
Binding sites differ in shape/ specificity/number	• Differential binding of molecules to type 1 and type 2 receptors • Activated by one (ACh) molecule or both (ACh and nicotine) molecules • No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)
Differential binding of molecules to type 1 and type 2 receptors	• Activated by one (ACh) or both (ACh and nicotine) molecules • No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)
Receptors activated by one (ACh) or both (ACh and nicotine) molecules	• No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)

✓

0	1	2

The student response earns two of the following points:

Description (2 points)

Points may be earned from only one row.

Structure (1 point maximum)	Function (1 point maximum)
Binding sites differ in shape/ specificity/number	• Differential binding of molecules to type 1 and type 2 receptors • Activated by one (ACh) molecule or both (ACh and nicotine) molecules • No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)
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Receptors activated by one (ACh) or both (ACh and nicotine) molecules	• No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)

Part B

1 point maximum

Description (1 point)

· Continued activation

· Repeated opening of sodium channels OR repeated depolarization OR muscle spasms

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0	1 ✓

The student response earns one of the following points:

Description (1 point)

· Continued activation

· Repeated opening of sodium channels OR repeated depolarization OR muscle spasms

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Acetylcholine receptor (AChR) proteins are found at the synapse between neurons and skeletal muscle cells. Acetylcholine released from neurons binds to a specific site on the receptor proteins, which causes an ion channel in the receptors to open and allow sodium ions (Na^+) to enter muscle cells. The resulting depolarization of muscle cells initiates muscle contractions. Another molecule, nicotine, can also bind to certain types of AChR proteins and activate the receptors.

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Please respond on separate paper, following directions from your teacher.

3. Acetylcholinesterase is an enzyme that breaks down acetylcholine in the synapse. **Describe** the effect of inhibiting acetylcholinesterase on the muscle cells with AChR type 2.

Please respond on separate paper, following directions from your teacher.

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General

2 points maximum.

Description (2 points)

Points may be earned from only one row.

Structure (1 point maximum)	Function (1 point maximum)
Binding sites differ in shape/ specificity/number	• Differential binding of molecules to type 1 and type 2 receptors • Activated by one (ACh) molecule or both (ACh and nicotine) molecules • No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)
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Receptors activated by one (ACh) or both (ACh and nicotine) molecules	• No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)

0	1	2

The student response earns two of the following points:

2 points maximum.

Description (2 points)

Points may be earned from only one row.

Structure (1 point maximum)	Function (1 point maximum)
Binding sites differ in shape/ specificity/number	• Differential binding of molecules to type 1 and type 2 receptors • Activated by one (ACh) molecule or both (ACh and nicotine) molecules • No difference in response (both open channels OR both result in depolarization OR both cause muscle contraction)
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General

1 point maximum.

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Description (1 point)

• Continued activation

• Repeated opening of sodium channels OR repeated depolarization OR muscle spasms

0	1 ✓

The student response earns one of the following points:

1 point maximum.

Description (1 point)

• Continued activation

• Repeated opening of sodium channels OR repeated depolarization OR muscle spasms

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4.

Figure 1. Diagram of the choice chamber used to measure host preference of mosquitoes

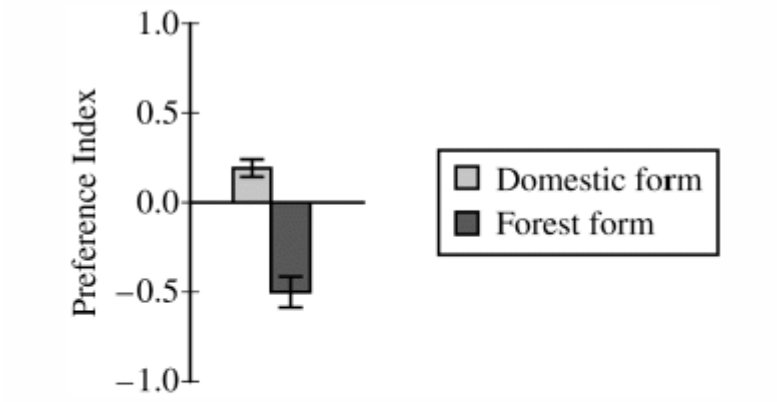

Figure 2. Mean host preference index $\pm 1SE_{\bar{Y}}$ of forest and domestic forms of mosquitoes. A positive value indicates preference for a human host, and a negative value indicates preference for a guinea pig host.

The yellow-fever mosquito (*Aedes aegypti*) is a major vector of human disease. In a particular location in Africa, there are two forms of the mosquito. The forest form of the mosquito is black and often lays its eggs in tree holes and pools of water in the forest. The domestic form of the mosquito is brown and prefers to lay its eggs in rainwater collected near human dwellings.

Researchers used a choice chamber (Figure 1) to investigate the host preference of *A. aegypti*. The researchers recorded the number of forest-form and domestic-form mosquitoes that bit human or guinea pig hosts during several ten-minute trials. The researchers used these data to calculate a host-preference index for each form, as shown in Figure 2. Researchers also identified a gene in the mosquitoes, *OR4*, that encodes an olfactory receptor. A volatile odorant, sulcatone, binds to the *OR4* receptor. Humans produce higher levels of sulcatone than do guinea pigs.

(a) Based on an analysis of the data, **identify** the preferred host of the forest form and of the domestic form of the mosquito.

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Please respond on separate paper, following directions from your teacher.

(b) **Propose a refinement** to the initial experimental design that will rule out the possibility that preference is based on a visual cue. **Propose** a different refinement to the initial experiment to test whether sulcatone is the attractant for the human-preferring form.

Please respond on separate paper, following directions from your teacher.

(c) **Predict** how each of the following mutations in the *OR4* gene would most likely affect the sensitivity of mosquitoes to sulcatone. **Justify** each prediction.

- *A mutation that results in the removal of the intracellular domain of the receptor protein*
- *A mutation that results in the substitution of a small hydrophobic amino acid for another small hydrophobic amino acid in the ligand-binding site of the receptor protein*

Please respond on separate paper, following directions from your teacher.

(d) A researcher proposes that the two forms of mosquito are evolving into two different species. **Identify** ONE potential postzygotic isolating mechanism, and **describe** how the isolating mechanism would result in the evolution of the two forms into different species.

Please respond on separate paper, following directions from your teacher.

Part A

2 points maximum

Identification (2 points)

· Forest mosquitoes prefer guinea pig

· Domestic mosquitoes prefer human hosts

0	1	2 ✓

Student response earns two of the following points

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Identification (2 points)

· Forest mosquitoes prefer guinea pig

· Domestic mosquitoes prefer human hosts

Part B

2 points maximum

Refinement: visual (1 point)

· Use a dark/no light box

· Cover the guinea pig/hand

· Use guinea pig/hand models

· Stop movement of guinea pig/hand

· Blind mosquitoes

Refinement: sulcatone (1 point)

· Use cotton ball/guinea pig/guinea-pig model soaked in sulcatone vs. control without sulcatone

· Use gloved/covered human hand that prevents odorant molecules from being released

· Remove or alter the OR4 gene in mosquitoes

0	1	2 ✓

Student response earns two of the following points

Refinement: visual (1 point)

· Use a dark/no light box

· Cover the guinea pig/hand

· Use guinea pig/hand models

· Stop movement of guinea pig/hand

· Blind mosquitoes

Refinement: sulcatone (1 point)

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· Use cotton ball/guinea pig/guinea-pig model soaked in sulcatone vs. control without sulcatone

· Use gloved/covered human hand that prevents odorant molecules from being released

· Remove or alter the OR4 gene in mosquitoes

Part C

4 points maximum

	Prediction (1 point each mutation; 2 points total)	**Justification (1 point each mutation; 2 points total)**
Removal of intracellular domain	Decreased sensitivity/insensitive	Unable to initiate intracellular signal/cascade
Substitution in ligand-binding site	No change (in sensitivity)	• Ligand can still bind to receptor • Conformation/shape of ligand-binding domain does not change
	Ligand can still bind to receptor	A similar amino acid leads to no/limited change to the structure of the protein

*other predictions may earn credit when appropriately justified

0	1	2	3	4 ✓

Student response earns four of the following points

	Prediction (1 point each mutation; 2 points total)	**Justification (1 point each mutation; 2 points total)**
Removal of intracellular domain	Decreased sensitivity/insensitive	Unable to initiate intracellular signal/cascade
Substitution in ligand-binding site	No change (in sensitivity)	• Ligand can still bind to receptor • Conformation/shape of ligand-binding domain does not change
	Ligand can still bind to receptor	A similar amino acid leads to no/limited change to the structure of the protein

*other predictions may earn credit when appropriately justified

Part D

2 points maximum

Identification (1 point)

· Hybrid inviability

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· Hybrid sterility

· Reduced hybrid fitness/hybrid breakdown

Description (1 point)

· Maintains reproductive isolation

· Prevents gene flow

0	1	2 ✓

Student response earns two of the following points

Identification (1 point)

· Hybrid inviability

· Hybrid sterility

· Reduced hybrid fitness/hybrid breakdown

Description (1 point)

· Maintains reproductive isolation

· Prevents gene flow

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Figure 1. Diagram of the choice chamber used to measure host preference of mosquitoes

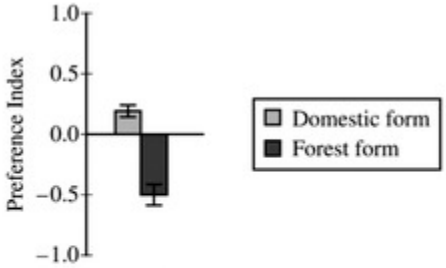

Figure 2. Mean host preference index $\pm 1SE_{\bar{x}}$ of forest and domestic forms of mosquitoes. A positive value indicates preference for a human host, and a negative value indicates preference for a guinea pig host.

The yellow-fever mosquito (*Aedes aegypti*) is a major vector of human disease. In a particular location in Africa, there are two forms of the mosquito. The forest form of the mosquito is black and often lays its eggs in tree holes and pools of water in the forest. The domestic form of the mosquito is brown and prefers to lay its eggs in rainwater collected near human dwellings.

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5. **Predict** how each of the following mutations in the *OR4* gene would most likely affect the sensitivity of mosquitoes to sulcatone. **Justify** each prediction.

- A mutation that results in the removal of the intracellular domain of the receptor protein
- A mutation that results in the substitution of a small hydrophobic amino acid for another small hydrophobic amino acid in the ligand-binding site of the receptor protein

Please respond on separate paper, following directions from your teacher.

Part c

4 point(s) maximum

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	Prediction (1 point each mutation; 2 points total)	**Justification (1 point each mutation; 2 points total)**
Removal of intracellular domain	Decreased sensitivity/insensitive	Unable to initiate intracellular signal/cascade
Substitution in ligand-binding site	No change (in sensitivity)	• Ligand can still bind to receptor • Conformation/shape of ligand-binding domain does not change
	Ligand can still bind to receptor	A similar amino acid leads to no/limited change to the structure of the protein

*other predictions may earn credit when appropriately justified

0	1	2	3	4 ✓

Student response earns 4 of the following 4 points

4 point(s) maximum

	Prediction (1 point each mutation; 2 points total)	**Justification (1 point each mutation; 2 points total)**
Removal of intracellular domain	Decreased sensitivity/insensitive	Unable to initiate intracellular signal/cascade
Substitution in ligand-binding site	No change (in sensitivity)	• Ligand can still bind to receptor • Conformation/shape of ligand-binding domain does not change
	Ligand can still bind to receptor	A similar amino acid leads to no/limited change to the structure of the protein

*other predictions may earn credit when appropriately justified

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6. Read each question carefully. Write your response in the space provided for each part of each question. Answers must be written out in paragraph form. Outlines, bulleted lists, or diagrams alone are not acceptable and will not be scored.

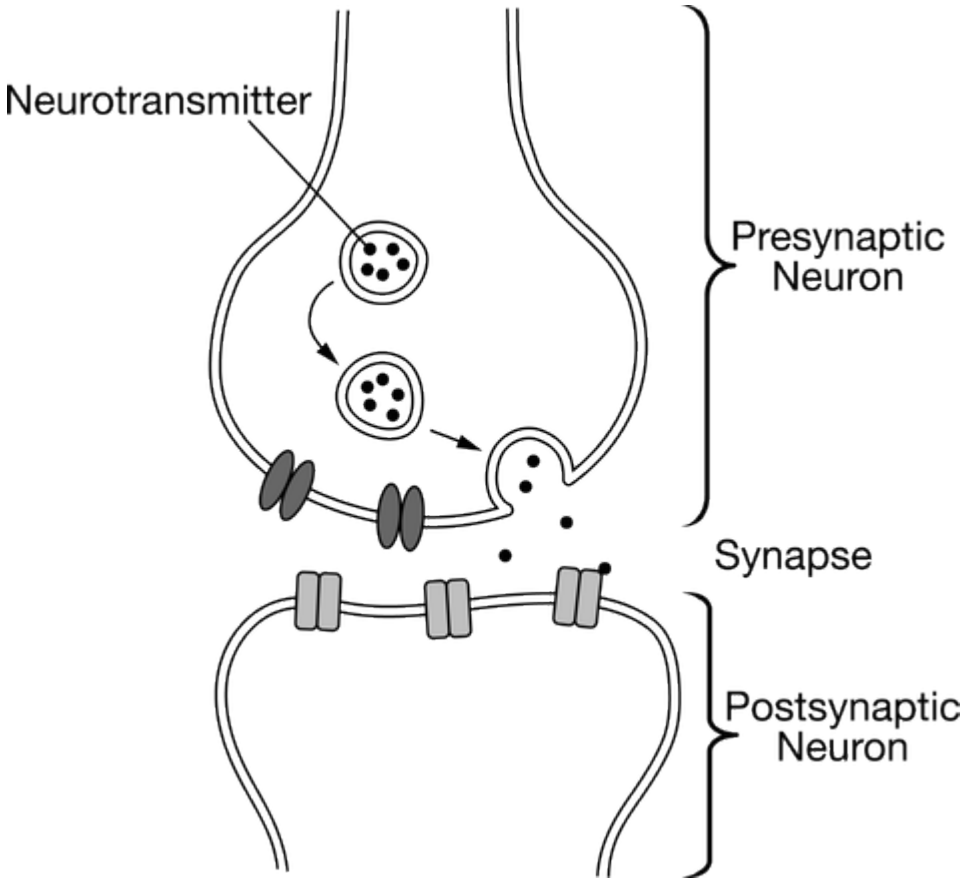

Figure 1. Release of neurotransmitters into the synapse in response to an action potential

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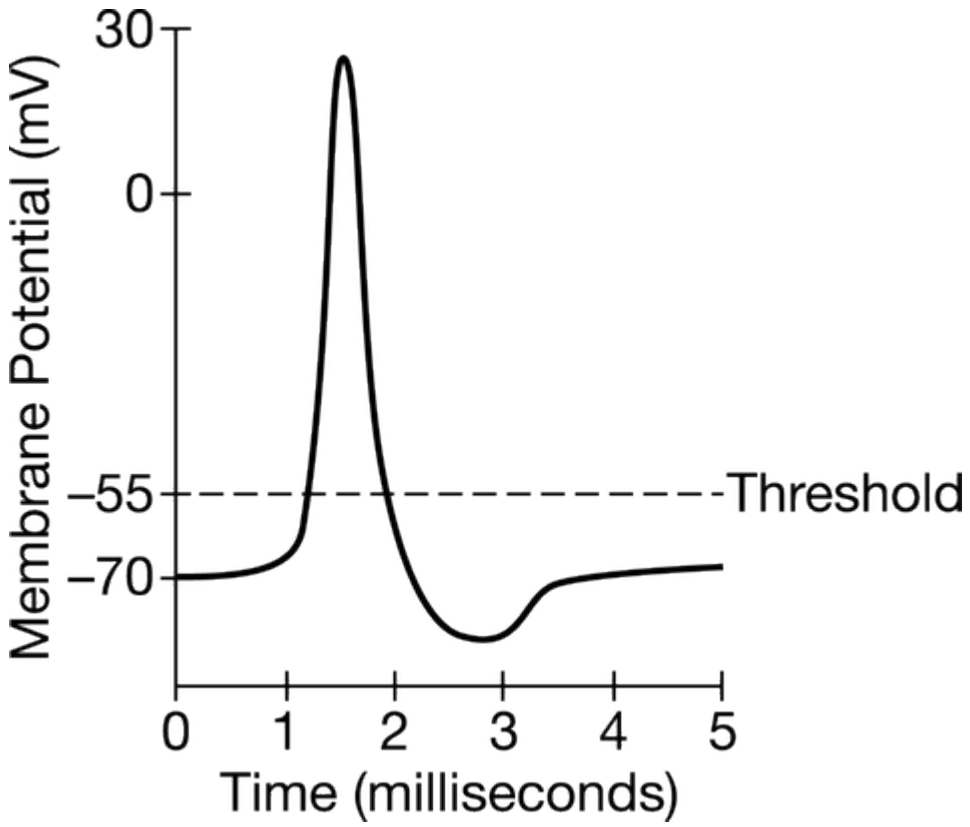

Figure 2. Model of a typical action potential in a neuron

Acetylcholine is a neurotransmitter that can activate an action potential in a postsynaptic neuron (Figures 1 and 2). A researcher is investigating the effect of a particular neurotoxin that causes the amount of acetylcholine released from presynaptic neurons to increase.

(a) **Describe** the immediate effect of the neurotoxin on the number of action potentials in a postsynaptic neuron. **Predict** whether the maximum membrane potential of the postsynaptic neuron will increase, decrease, or stay the same**.**

Please respond on separate paper, following directions from your teacher.

(b) The researcher proposes two models, A and B, for using acetyl-cholinesterase (AChE), an enzyme that degrades acetylcholine, to prevent the effect of the neurotoxin. In model A, AChE is added to the synapse. In model B, AChE is added to the cytoplasm of the postsynaptic cell. **Predict** the effectiveness of EACH proposed model. **Provide reasoning** to support your predictions.

Please respond on separate paper, following directions from your teacher.

Part A

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Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

The response includes both of the following criteria.

- [ ] The description that the neurotoxin will increase the number of action potentials
- [ ] The prediction that the maximum membrane potential of the postsynaptic neuron will stay the same

Part B

Select a point value to view scoring criteria, solutions, and/or examples and to score the response.

0	1	2 ✓

The response includes both of the following predictions.

- [ ] Model A is effective because acetylcholine is in the synapse.
- [ ] Model B is not effective because acetylcholine is not in the cytoplasm of the postsynaptic cell.