Past-paper walk-through

Cell Communication ▪ 4.1

eXercise

Questions in this set

- 2025 Q2
- 2019 Q4
- 2018 Q2
- 2016 Q8

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 2

2025 ▪ Q2

Many insects rely on pheromones (chemical signals) that are released by the females to find mating partners. Scientists hypothesize that, in a certain type of moth, the behavior of male moths in response to pheromones is regulated by the extracellular signaling molecule 20E.

(a) Many receptors are embedded in the plasma membrane. Describe the polarity of the portion of the receptor that is inside the membrane.

To investigate whether the binding of 20E to its receptor, DopEcR, affects behavior in moths, scientists injected male moths with saline (control solution) or with small interfering RNA molecules (siRNAs) that inhibit the expression of the gene encoding DopEcR. The scientists then exposed the moths to the pheromone and determined the percent of total time observed that the moths engaged in general activity, defined as movement in any direction. The scientists also determined the percent of the general

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activity time that the moths spent in oriented activity, defined as movement toward an area of high pheromone concentration (Table 1).

Table 1. Average General and Oriented Activity in Male Moths Injected With Saline or siRNA Molecules

Treatment	General Activity (percent of total time observed, average $\pm 2\mathrm{SE}_{\bar{x}}$)	Oriented Activity (percent of general activity, average $\pm 2\mathrm{SE}_{\bar{x}}$)
Male moths injected with saline (control solution)	95 ± 5	60 ± 4
Male moths injected with siRNAs that inhibit expression of the gene encoding DopEcR	90 ± 8	25 ± 6

DopEcR is a G protein-coupled receptor. When 20E binds to DopEcR, GTP displaces the GDP bound to the G protein, and a signaling pathway is activated. The scientists hypothesize that this leads to the transcription of genes associated with the oriented activity observed in the male moths (Figure 1).

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Figure 1. A simplified model of a signaling pathway activated by the binding of 20E to its receptor, DopEcR
[Diagram of a signaling pathway across a plasma membrane. On the left: a molecule labeled "20E" (circle) approaches a membrane receptor labeled "DopEcR" embedded in the "Plasma Membrane" (drawn as two parallel wavy lines). Below the receptor inside the membrane, an inactive "G-Protein (Inactive)" complex is shown as an oval labeled "Gα" bound to "GDP". On the right: after 20E binds DopEcR, a second receptor is shown with an active "G-Protein (Active)" complex, labeled "Gα" bound to "GTP" (shown as a jagged/starburst shape indicating activation), with an arrow pointing down to the text "Increased Expression of Genes Associated with Oriented Activity in Male Moths".]

Question 2

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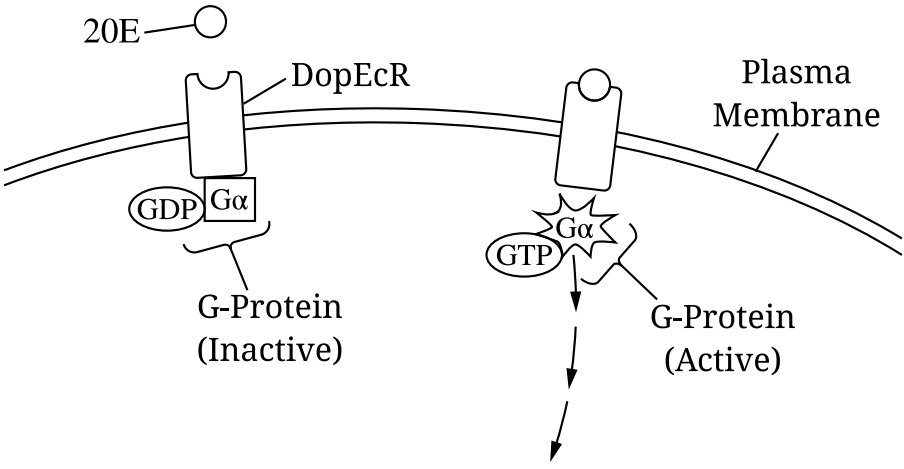

20E
DopEcR
Plasma
Membrane
GDP
Gα
G-Protein
(Inactive)
Gα
GTP
G-Protein
(Active)

Question 2

2025 ▪ Q2

Many insects rely on pheromones (chemical signals) that are released by the females to find mating partners. Scientists hypothesize that, in a certain type of moth, the behavior of male moths in response to pheromones is regulated by the extracellular signaling molecule 20E.

(b)(i) Using the template in the space provided for your response, construct an appropriate type of graph that represents the data in Table 1. Your graph should be appropriately plotted and labeled.

(b)(ii) Based on the data in Table 1, determine the type of activity that was affected by inhibiting the expression of the DopEcR receptor.

Question 2

2025 ▪ Q2

Many insects rely on pheromones (chemical signals) that are released by the females to find mating partners. Scientists hypothesize that, in a certain type of moth, the behavior of male moths in response to pheromones is regulated by the extracellular signaling molecule 20E.

(c)(i) Based on Table 1, identify the treatment group in which the oriented activity was greater than 50% of the general activity.

(c)(ii) The scientists studied some moths with a mutation in the gene encoding the G protein. The mutation prevents GTP from displacing the GDP bound to the G protein. Based on Figure 1, predict the effect of this mutation on the oriented activity in male moths exposed to the pheromone.

Question 2

2025 ▪ Q2

Many insects rely on pheromones (chemical signals) that are released by the females to find mating partners. Scientists hypothesize that, in a certain type of moth, the behavior of male moths in response to pheromones is regulated by the extracellular signaling molecule 20E.

(d)(i) Expression of the gene encoding DopEcR is low in the male moths during their first few days as adults, when they are sexually immature. Gene expression rapidly increases as the moths reach sexual maturity. The scientists claim that this increase in gene expression increases the likelihood of males finding females with whom to mate. Use evidence from the information provided to support the scientists' claim.

(d)(ii) Based on Figure 1, explain how an inhibitor of the DopEcR pathway might serve as an effective chemical to protect crops from moth damage.

Solution 2

(a)

Mark scheme

- The portion of the receptor inside the membrane is nonpolar/hydrophobic, consistent with the hydrophobic interior of the phospholipid bilayer it spans.

Solution 2

(b)(i) Mark scheme

- Construct an appropriate graph of the Table 1 data; 3 points total, one for each of: (1) choosing an appropriate graph type — a bar graph or modified/grouped bar graph showing General Activity and Oriented Activity (percent) for both the saline/control and siRNA treatment groups; (2) accurately plotting the data with error bars — Saline: General 95 ± 5, Oriented 60 ± 4; siRNA: General 90 ± 8, Oriented 25 ± 6 (using the table's $\pm 2SE_{\bar{x}}$ values); (3) appropriately labeling the graph — axis titles/units (e.g., percent), a legend or clear grouping distinguishing treatment and activity type. Grade a student's described or drawn graph against these three criteria.

Solution 2

(b)(ii)

Mark scheme

- Oriented activity was the type of activity affected by inhibiting DopEcR expression (it dropped from 60% to 25% of general activity), while general activity was comparatively unaffected (95% vs 90%).

Solution 2

(c)(i)

Mark scheme

- The control/saline-treated group (male moths injected with saline/control solution): oriented activity (60%) was greater than 50% of general activity (95%) in that group, whereas the siRNA group's oriented activity (25%) was well under 50% of its general activity (90%).

Solution 2

(c)(ii)

Mark scheme

- The moths will show decreased oriented activity. Because the mutation prevents GTP from displacing GDP on the G protein, the G protein cannot become active, so the downstream signaling pathway that increases expression of genes associated with oriented activity is not activated.

Solution 2

(d)(i)

Mark scheme

- Any one line of evidence is sufficient: increased DopEcR expression will increase oriented activity (and thus the moths' ability to find a mate); an increase in DopEcR expression will enable binding of 20E to more receptors; an increase in DopEcR expression will make males more sensitive to pheromones released by females — all consistent with higher DopEcR expression at sexual maturity improving mate-finding.

Solution 2

(d)(ii)

Mark scheme

- An inhibitor of the DopEcR pathway will reduce oriented activity / reduce expression of genes associated with oriented activity, and therefore decrease mating success and population growth of the moths — reducing crop damage by lowering the pest population.

Question 4

2019 ▪ Q4

[Figure 1. Release of neurotransmitters into the synapse in response to an action potential: a diagram of a presynaptic neuron terminal releasing "Neurotransmitter" molecules (packaged in vesicles) into the "Synapse", which are received by receptor channels on the "Postsynaptic Neuron" membrane.]

[Figure 2. Model of a typical action potential in a neuron: a graph of Membrane Potential (mV) on the y-axis (labeled -70, -55, 0, 30) versus Time (milliseconds) on the x-axis (0 to 5); a dashed horizontal line at -55 mV labeled "Threshold"; the curve starts at resting potential -70 mV, rises sharply to a peak of about +30 mV around t=1.5 ms, then falls rapidly, undershoots to about -75 mV around t=3 ms, and returns gradually toward -70 mV by t=5 ms.]

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

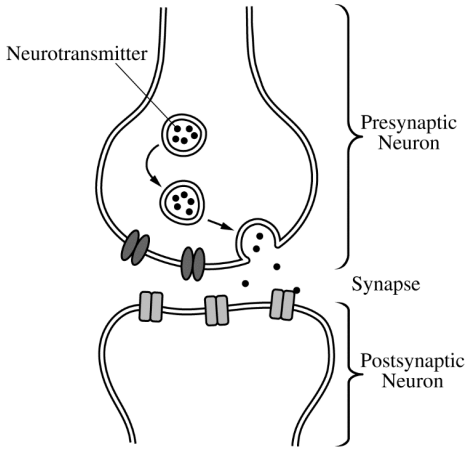
Question 4

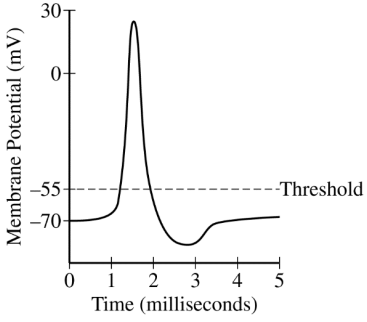
particular neurotoxin that causes the amount of acetylcholine released from presynaptic neurons to increase.

(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.

(b) The researcher proposes two models, A and B, for using acetylcholinesterase (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.

Question 4


Neurotransmitter
Presynaptic Neuron
Synapse
Postsynaptic Neuron


30
0
–55
–70
Threshold
Membrane Potential (mV)
0
1
2
3
4
5
Time (milliseconds)

Solution 4

(a) Mark scheme

- Description: The immediate effect of the neurotoxin (which increases acetylcholine released from presynaptic neurons) is to increase the number/frequency of action potentials generated in the postsynaptic neuron, since more neurotransmitter binding means the postsynaptic membrane reaches threshold more often. [1 point] Prediction: The maximum membrane potential (peak amplitude) of each postsynaptic action potential will stay the same — the toxin increases how often an action potential fires, not the peak voltage an individual action potential reaches (which is set by the same voltage-gated channels regardless of stimulus frequency). [1 point]

Solution 4

(b) Mark scheme

- Model A (AChE added to the synapse): Predicted effective. Reasoning — acetylcholine released by the presynaptic neuron acts in the synapse, so AChE present there can degrade it before it binds and overstimulates postsynaptic receptors, counteracting the neurotoxin's effect. [1 point] Model B (AChE added to the cytoplasm of the postsynaptic cell): Predicted not effective. Reasoning — acetylcholine is never present in the cytoplasm of the postsynaptic cell (it acts extracellularly, binding receptors on the postsynaptic membrane from the synaptic side), so intracellular AChE has no acetylcholine to degrade and cannot prevent the toxin's effect. [1 point]

Question 2

2018 ▪ Q2

Question 2

[Figure 1: Diagram of cellular response to infection by pathogenic bacteria. At the top is a double-line "Cell Membrane" with two small vertical channel/pore segments embedded in it, arrows converging up into the pore from below (labeled with circled "3"), and one arrow pointing up and out through the membrane at the far left (from the Active Interleukin). Below the membrane, left region: "Inactive Interleukin" (drawn as a triangle attached to an oval) is converted via a step labeled circled "2" into "Active Interleukin" (an oval with a triangle nearby, arrow pointing up out of the membrane, showing the active portion is released from the cell). Middle-right region: "N-terminal Gasdermin" (a small rectangle/bracket shape) sits just below the membrane pore; "Gasdermin" (a rectangle attached to a filled black square) is converted via a step labeled circled "3" into N-terminal Gasdermin, which is shown assembling into the membrane pore. Bottom-left region: "Inactive Caspase-1" (a filled circle attached to an oval) is converted via a step labeled circled "1", triggered by "Bacterial Infection" (arrow pointing up into step 1), into "Active Caspase-1" (an oval with a filled circle nearby); Active

Question 2

Caspase-1 then has arrows pointing to both step 2 (activating Interleukin) and step 3 (activating Gasdermin). Caption: "Figure 1. Cellular response to infection by pathogenic bacteria."]

Question 2

Some pathogenic bacteria enter cells, replicate, and spread to other cells, causing illness in the host organism. Host cells respond to these infections in a number of ways, one of which involves activating particular enzymatic pathways (Figure 1). Cells normally produce a steady supply of inactive caspase-1 protein. In response to intracellular pathogens, the inactive caspase-1 is cleaved and forms an active caspase-1 (step 1). Active caspase-1 can cleave two other proteins. When caspase-1 cleaves an inactive interleukin (step 2), the active portion of the interleukin is released from the cell. An interleukin is a signaling molecule that can activate the immune response. When caspase-1 cleaves gasdermin (step 3), the N-terminal portions of several gasdermin proteins associate in the cell membrane to form large, nonspecific pores.

Question 2

Researchers created the model in Figure 1 using data from cell fractionation studies. In the experiments, various parts of the cell were separated into fractions by mechanical and chemical methods. Specific proteins known to be located in different parts of the cell were used as markers to determine the location of other proteins. The table below shows the presence of known proteins in specific cellular fractions.

CELL FRACTIONS CONTAINING DIFFERENT CELLULAR PROTEINS

	Aconitase (Krebs cycle protein)	**DNA poly-merase**	**GAPDH (glycolytic protein)**	**Sodium-potassium pump**	**NF-κB (Immune response protein)**
Whole cell sample	+	+	+	+	+
Fraction 1	+				
Fraction 2		+			+
Fraction 3			+		+
Fraction 4				+	

Question 2

- = presence of protein

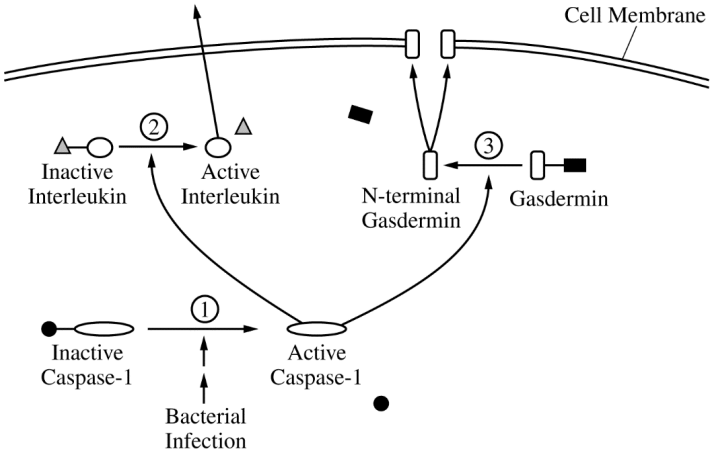
(a) Describe the effect of inhibiting step 3 on the formation of pores AND on the release of interleukin from the cell.

Question 2

CELL FRACTIONS CONTAINING DIFFERENT CELLULAR PROTEINS

	Aconitase (Krebs cycle protein)	DNA polymerase	GAPDH (glycolytic protein)	Sodium-potassium pump	NF-κB (Immune response protein)
Whole cell sample	+	+	+	+	+
Fraction 1	+				
Fraction 2		+			+
Fraction 3			+		+
Fraction 4				+	
+ = presence of protein					

Question 2


Cell Membrane
2
Inactive
Interleukin
Active
Interleukin
3
N-terminal
Gasdermin
Gasdermin
1
Inactive
Caspase-1
Active
Caspase-1
Bacterial
Infection

Question 2

2018 ▪ Q2

Question 2

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Question 2

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Fraction 4				+	