2021

AP® Biology

Sample Student Responses and Scoring Commentary

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Question 6: Analyze Data — 4 points

The small invertebrate krill species *Thysanoessa inermis* is adapted to cold (4°C) seawater. Over the past ten years, there has been a gradual increase in the water temperature of the krill's habitat. A sustained increase in water temperature may ultimately affect the ability of the krill to survive.

One effect of higher temperatures is protein misfolding within cells. Krill have several *hsp* genes that code for heat-shock proteins (HSPs). These proteins help prevent protein misfolding or help to refold proteins to their normal shapes.

Scientists conducted experiments on *T. inermis* to detect changes in the expression of *hsp* genes when the krill were exposed to temperatures above 4°C. An experimental group of krill was maintained in tanks with 4°C seawater and then placed into tanks with 10°C seawater for approximately three hours. The krill were then given a six-hour recovery period in the 4°C seawater tanks. A control group of krill was moved from a tank of 4°C seawater to another tank of 4°C seawater for approximately three hours and then returned to the original tank. The scientists analyzed *hsp* gene expression by measuring the concentrations of three mRNAs (I, II, III) transcribed from certain *hsp* genes in both the heat-shocked krill (Figure 1) and the control krill. For the control krill, no transcription of the *hsp* genes was detected throughout the test period (data not shown).

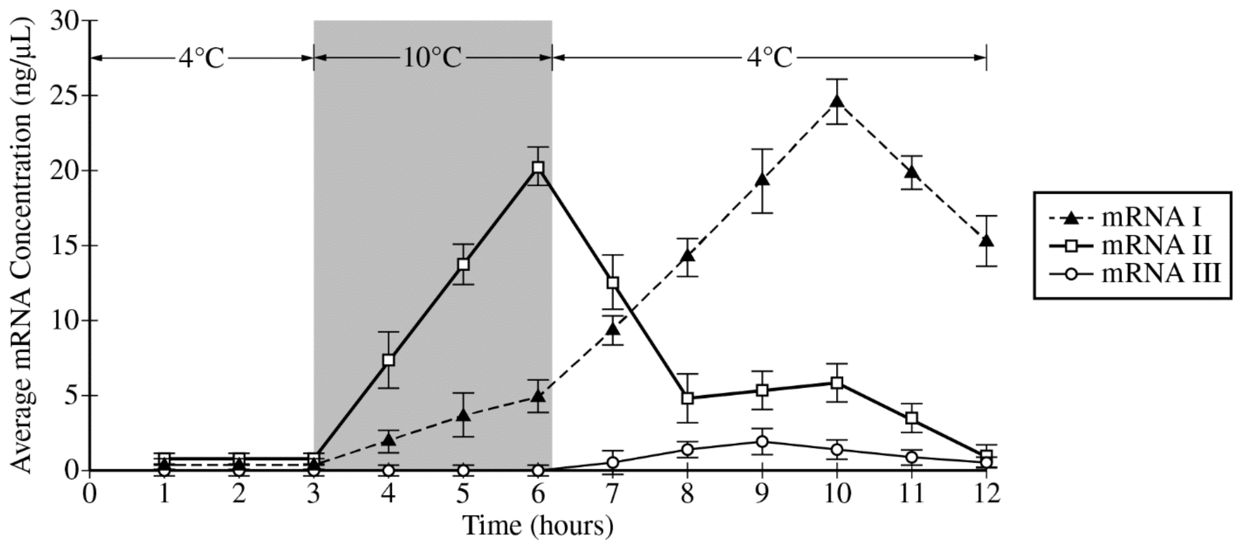

Figure 1. Average concentration of three mRNAs (I, II, III) transcribed from *hsp* genes in krill heat shocked at 10°C. Error bars represent $\pm 2SE_{\bar{X}}$.

(a)	**Identify** the *hsp* mRNA that has the slowest rate of concentration increase in response to heat-shock treatment. • (mRNA) III	**1 point**
(b)	**Describe** the trend in the average concentration of mRNA I throughout the experiment. • (No change in concentration from 1 to 3 hours) increased concentration (slightly) between 3 and 6 hours/during the heat shock, increased concentration at a greater rate from 6 to 10 hours/for 4 hours after the heat shock, and then decreased concentration after hour 10.	**1 point**

(c)	The scientists hypothesized that the heat-shock protein (HSP) translated from mRNA I plays a greater role in refolding proteins than does the HSP translated from mRNA II. Use the data to **support** the hypothesis. • mRNA I is still expressed at a high level after the heat-shock period, while mRNA II levels decrease after the heat shock, when proteins would need to be refolded.	**1 point**
(d)	mRNAs I and II are transcribed from the same gene. **Explain** how a cell can produce two different mRNAs from the same gene. Accept one of the following: • The cell expresses different exons/performs alternative splicing. • The cell uses different transcription termination sites (poly(A) sites). • The cell uses different promoters.	**1 point**
	Total for question 6	**4 points**

Begin your response to **QUESTION 6** on this page. Do not skip lines.

a) The hsp mRNA III has the slowest rate of concentration increase in response to heat-shock treatment, as shown on the graph.

b) When the krill are in 4°C water, there is no mRNA I. When the krill are placed in 10°C tanks, the concentration of mRNA I increases from 0 to 5 ng/μL. When the krill are placed back in 4°C tanks for a 6 hour recovery, mRNA I concentration increases for the first 4 hours from 5 to 25 ng/μL, then decreases for the final 2 hours from 25 to 17 ng/μL.

c) The graph shows that the mRNA I concentration increases most drastically after the krill are moved back to 4°C. This suggests that after krill proteins are denatured, then mRNA I is transcribed at a greater frequency to refold the denatured proteins correctly. By contrast, mRNA II has a steep dropoff in concentration after the krill are moved back to 4°C, indicating that it is not involved in refolding denatured proteins.

Continue your response to **QUESTION 6** on this page. Do not skip lines.

d) A cell can produce two different mRNAs from the same gene through a process called alternative RNA splicing. Genes contain coding regions called exons that alternate with noncoding regions called introns. When transcription occurs, the pre-mRNA transcript has both exons and introns. The transcript then has its introns removed by a spliceosome and the exons are joined together. In alternative RNA splicing, different mRNAs can be produced depending on which regions are treated as exons and which are treated as introns.

Begin your response to QUESTION 6 on this page. Do not skip lines.

a) mRNA III

b) mRNA started increasing in concentration during the heatshock and then increased more rapidly after the heat shock and then finally decreased at about the same rate at about 10 hrs.

c) Since mRNA I increase the highest right after heat shock this sugest that it is used to reshape the proteins because it is increasing after the proteins got misshappen during the heat shock. mRNA II's biggest increase is during the heat shock. This sugegests it is used to make proteins that help prevent protein misfolding rather than refold them.

d) On a single gene there are many different sections that code for different genes. Both mRNAs I and II were transcribed from different parts of the gene that coded for different traits or expression. The cells transcribes each unique code from the DNA into RNA and then uses the RNA code to translate the codons into a unique Amino Acids based on the unique

Continue your response to **QUESTION 6** on this page. Do not skip lines.

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Begin your response to QUESTION 6 on this page. Do not skip lines.

(a) mRNA III had the slowest rate of increase.

(b) The rate of mRNA concentration increased until 10 hours for mRNA I, at which point it began to decrease at the same rate.

(c) HSP from mRNA I plays a greater role because it has a higher maximum mRNA concentration. The increased mRNA concentration means more HSP can be made and more refolding can occur.

(d) The same gene may have different encoding sections and transcription factors on it. Thus, one gene can allow different mRNAs to be produced by regulating the expression and regulation of portions of genetic code.

Question 6

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

This question was based on a species of krill, *Thysanoessa inermis*, that is adapted to cold seawater. The question described experiments used to detect changes in expression of *hsp* genes that code for heat-shock proteins (HSPs). Average concentrations of mRNAs transcribed from three *hsp* genes in krill before, during, and after a heat shock treatment were presented in a graph (Figure 1).

In part (a) students were asked to identify the *hsp* mRNA that has the slowest rate of concentration increase in response to the heat shock treatment. Responses were expected to demonstrate proficiency in describing data from a graph (Science Practice 4.B).

In part (b) students were asked to describe the trend in average concentration of mRNA I throughout the experiment. Responses were expected to demonstrate proficiency in describing data from a graph (Science Practice 4.B).

In part (c) students were asked to use experimental data to support the scientists' claim that the HSP translated from mRNA I plays a greater role in refolding proteins than does the HSP translated from mRNA II . Responses were expected to demonstrate proficiency in describing data from a graph (Science Practice 4.B), that gene regulation results in differential gene expression (IST-2.D.1 in Topic 6.6), and an understanding of how heat can denature proteins (ENE-1.F.1 in Topic 3.3).

In part (d) students were asked to explain how a cell can produce two different mRNAs from the same gene. Responses were expected to demonstrate an understanding of alternative splicing (IST-1.N.6 in Topic 6.3).

Sample: 6A
Score: 4

The response earned 1 point in part (a) for identifying mRNA III . The response earned 1 point in part (b) for describing the trend mRNA I makes throughout the experiment and providing concentrations and times to indicate changes in rates. The response earned 1 point in part (c) for supporting the hypothesis that " mRNA I concentration increases" after the heat-shock period where "krill proteins are denatured," while mRNA II "has a steep dropoff" after the heat shock and "is not involved in refolding denatured proteins." The response earned 1 point in part (d) for explaining "alternative RNA splicing."

Sample: 6B
Score: 3

The response earned 1 point in part (a) for identifying mRNA III . The response earned 1 point in part (b) for describing the phases and changes of mRNA I concentration throughout the experiment, concluding with decreasing at "about 10 hours." The response earned 1 point in part (c) for supporting that mRNA I levels are "the highest right after heat shock," when HSP translated from mRNA I is "used to reshape the proteins ... misshappen during the heat shock." The response did not earn a point in part (d) because "a single gene ... code for different genes" and "translate the codons into a unique Amino Acids" does not explain alternative splicing.

Question 6 (continued)

Sample: 6C
Score: 1

The response earned 1 point in part (a) for identifying mRNA III. The response did not earn a point in part (b) because "mRNA concentration increased until 10 hours" does not describe the details of concentration changes at each phase of the experiment. The response did not earn a point in part (c) because, while the concentration of mRNA I is addressed, there is no discussion of proteins needing to be refolded after heat shock. The response did not earn a point in part (d) because "the same gene may have different encoding sections and transcription factors on it" does not address expression of different exons/alternative splicing.