AP Bio FRQ Fridays

2021 #6
mRNA, Alternative Splicing, & Protein Denaturation

FRQ Friday #18

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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).

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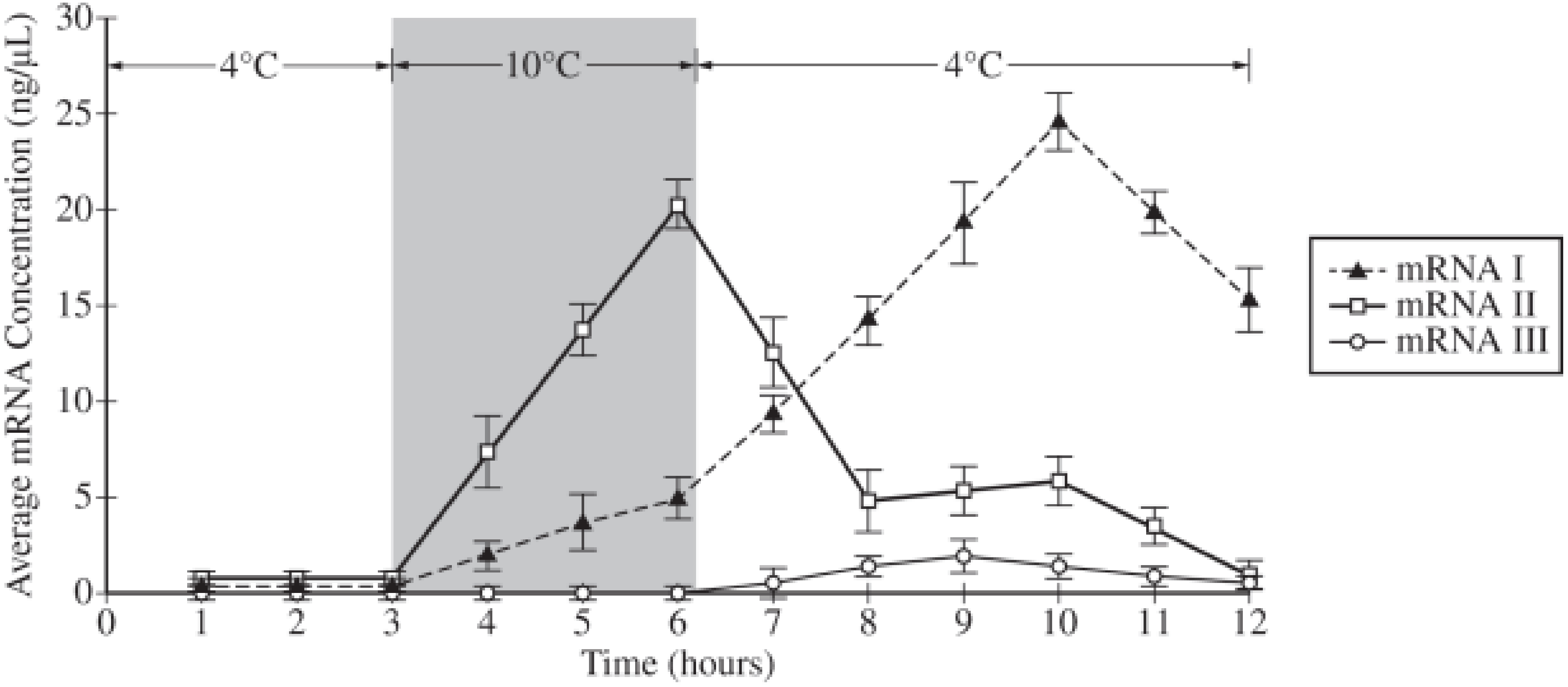

Figure 1. Average concentration of three mRNAs (I, II, III) transcribed from *hsp* genes in krill heat shocked at 10°C. Error bars represent $\pm 2SE_{\bar{x}}$.

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(a) **Identify** the *hsp* mRNA that has the slowest rate of concentration increase in response to heat-shock treatment.

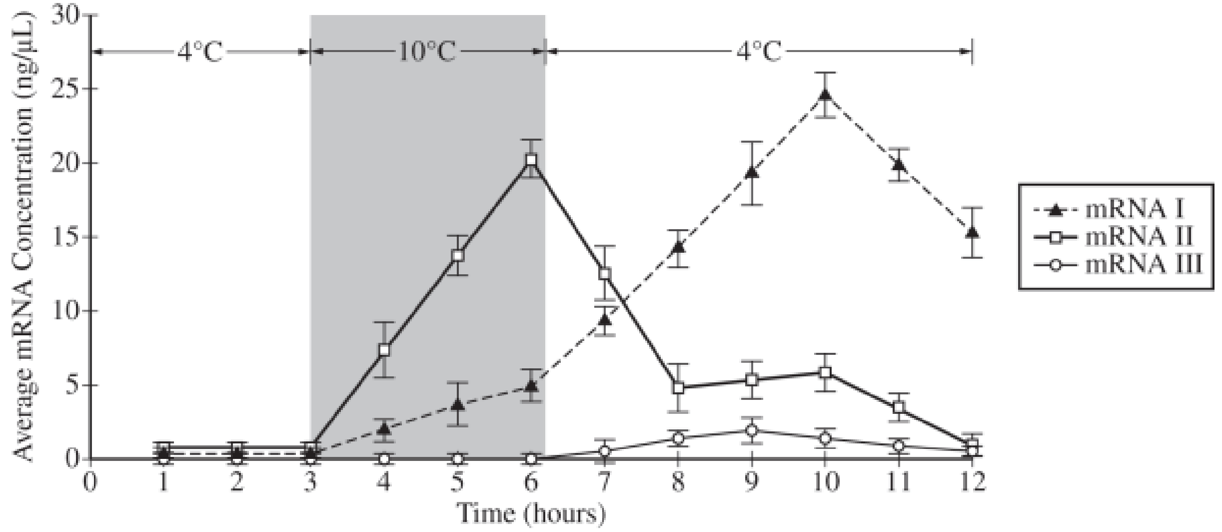

Figure 1. Average concentration of three mRNAs (I, II, III) transcribed from *hsp* genes in krill heat shocked at 10°C. Error bars represent $\pm 2SE_{\bar{x}}$.

- (mRNA) III

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

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(b) **Describe** the trend in the average concentration of mRNA I throughout the experiment.

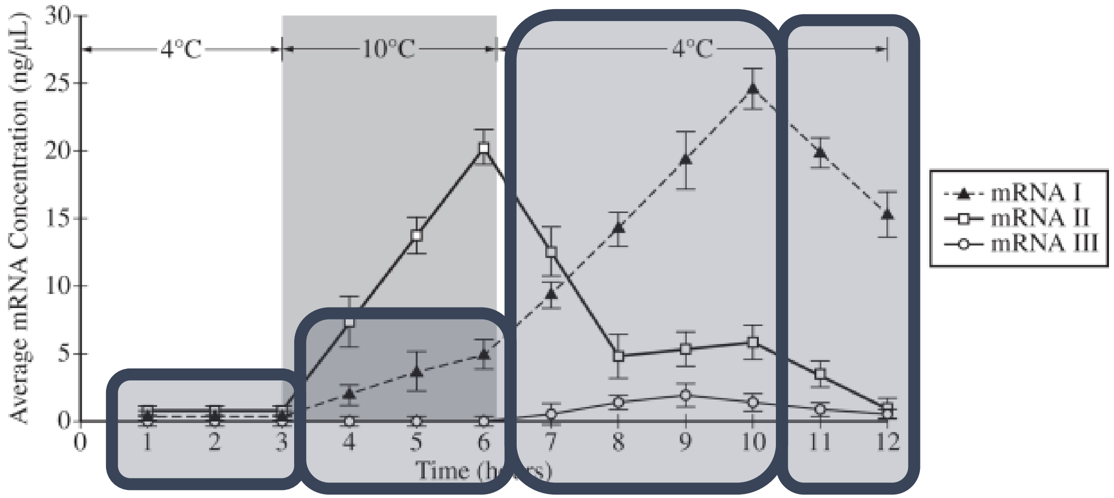

Figure 1. Average concentration of three mRNAs (I, II, III) transcribed from *hsp* genes in krill heat shocked at 10°C. Error bars represent $\pm 2SE_{\bar{x}}$.

- (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.

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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.

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(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.

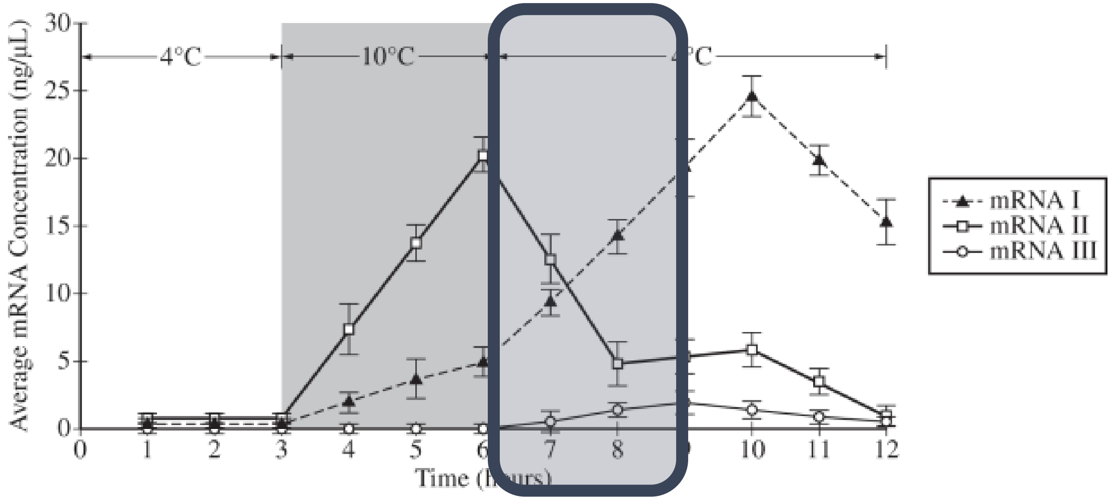

Figure 1. Average concentration of three mRNAs (I, II, III) transcribed from *hsp* genes in krill heat shocked at 10°C. Error bars represent $\pm 2SE_{\bar{x}}$.

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(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.

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.

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(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.

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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.