2024

AP® Biology

Sample Student Responses and Scoring Commentary

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Free-Response Question 5

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

Question 5: Analyze Model or Visual Representation of a Biological Concept or Process — 4 points

Researchers study mechanisms that enable or prevent speciation.

New genes can evolve from noncoding regions of DNA. It is not until certain regulatory elements are present in the DNA that a noncoding region becomes a new, functional gene that encodes a protein. These regulatory elements include a promoter, a 5′ untranslated region (UTR) followed by a start codon, and a 3′ UTR following a stop codon (Figure 1).

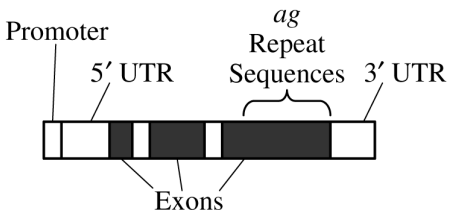
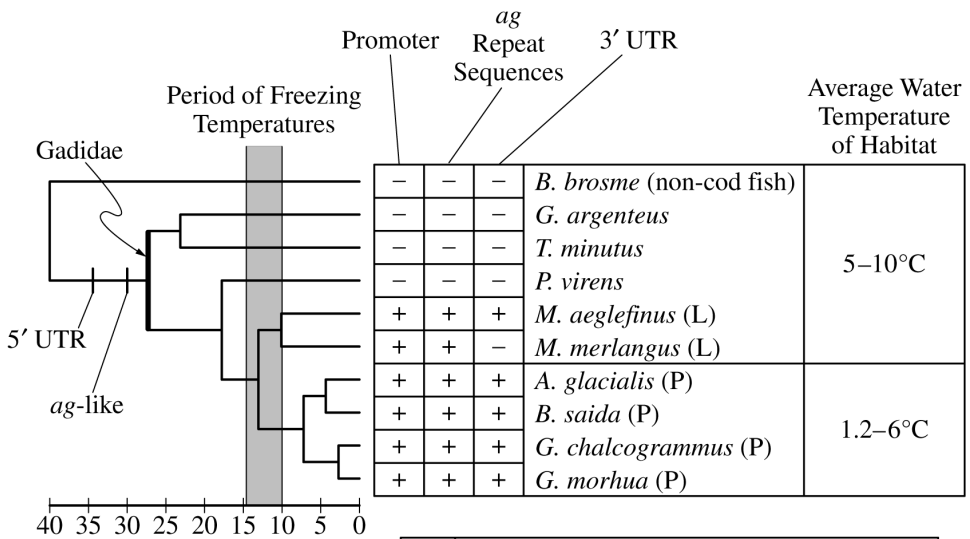


Figure 1. Basic structure of a functional *ag* gene

Researchers studied the evolution of the family of antifreeze-glycoprotein (AG) encoding genes in Gadidae, a family of marine fish known as cods. When present in the fish, these glycoproteins reduce the freezing temperature of the fish. The researchers compared genomic sequences in nine cod species and one non-cod fish species, *B. brosme*. They recorded the presence or absence of the elements of functional *ag* genes as well as *ag*-like sequences that are similar to a functional gene but have undergone mutation and do not contain all the elements required to enable protein production (Figure 2).



–	–	–	*B. brosme* (non-cod fish)	5–10°C
–	–	–	*G. argenteus*	
–	–	–	*T. minutus*	
–	–	–	*P. virens*	
+	+	+	*M. aeglefinus* (L)	
+	+	–	*M. merlangus* (L)	
+	+	+	*A. glacialis* (P)	1.2–6°C
+	+	+	*B. saida* (P)	
+	+	+	*G. chalcogrammus* (P)	
+	+	+	*G. morhua* (P)	

–	Element is absent.
+	Element is present.
L	Functional *ag* genes are lost.
P	Functional *ag*-encoded proteins are present.

Figure 2. Phylogenetic tree showing the evolution of *ag* genes

(a) **Describe** a post-zygotic mechanism that prevents gene flow and thus enables speciation. **1 point**

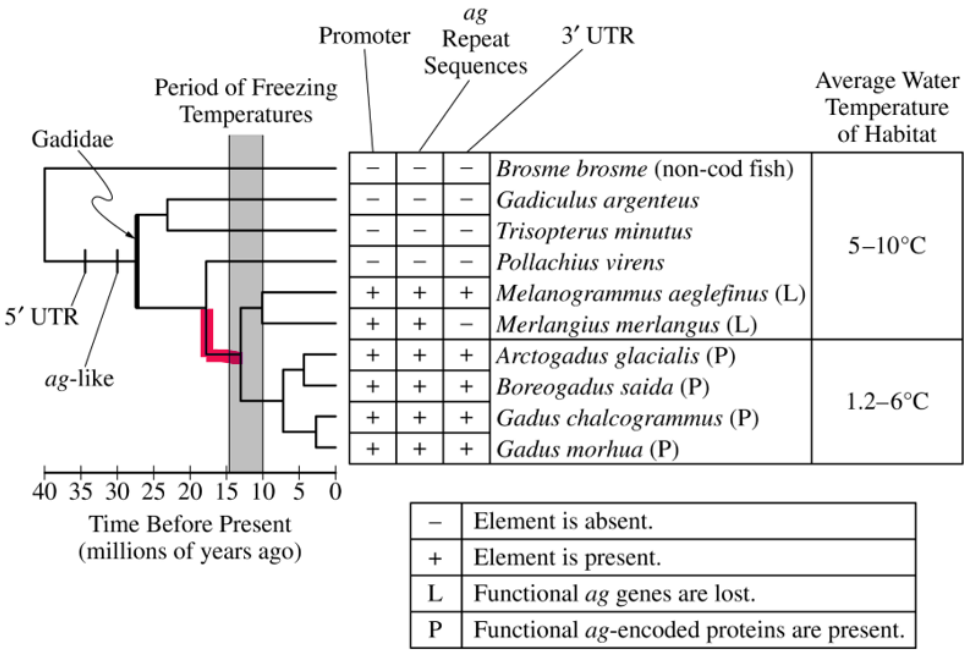
- The offspring do not survive (long enough to reproduce)/cannot (successfully) reproduce.

(b) Based on the data in Figure 2, **explain** how changes to the genome enabled cods to survive and reproduce after a period of freezing temperatures between 10 and 15 million years ago. **1 point**

- (Over time) the addition of the promoter/*ag* repeat sequences/3′ UTR/regulatory elements led to emergence of new genes/*ag* genes/functional gene products (that prevent freezing).

(c) Using the template in the space provided for your response, place an "X" on the phylogenetic tree to **represent** the origin of the functional *ag* gene. **1 point**

- An X is placed anywhere along the colored L-shaped line in the figure.



–	–	–	*Brosme brosme* (non-cod fish)	5–10°C
–	–	–	*Gadiculus argenteus*	
–	–	–	*Trisopterus minutus*	
–	–	–	*Pollachius virens*	
+	+	+	*Melanogrammus aeglefinus* (L)	
+	+	–	*Merlangius merlangus* (L)	
+	+	+	*Arctogadus glacialis* (P)	1.2–6°C
+	+	+	*Boreogadus saida* (P)	
+	+	+	*Gadus chalcogrammus* (P)	
+	+	+	*Gadus morhua* (P)	

–	Element is absent.
+	Element is present.
L	Functional *ag* genes are lost.
P	Functional *ag*-encoded proteins are present.

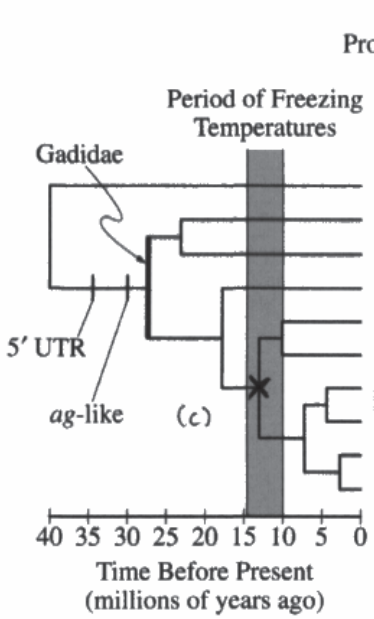
(d) Based on Figure 2, **explain** how genetic differences among the species in the Gadidae family determine the habitats in which they can survive. **1 point**

- Species with the functional *ag* gene/antifreeze glycoprotein are able to live in colder water/lower temperatures (than are species without the functional gene).

Total for question 5 **4 points**

BEGIN Question 5

Begin your response to **QUESTION 5** on this page. Do not skip lines.



Promoter	ag Repeat Sequences	3′ UTR		Average Water Temperature of Habitat
–	–	–	*B. brosme* (non-cod fish)	5–10°C
–	–	–	*G. argenteus*	
–	–	–	*T. minutus*	
–	–	–	*P. virens*	
+	+	+	*M. aeglefinus* (L)	
+	+	–	*M. merlangus* (L)	
+	+	+	*A. glacialis* (P)	1.2–6°C
+	+	+	*B. saida* (P)	
+	+	+	*G. chalcogrammus* (P)	
+	+	+	*G. morhua* (P)	

–	Element is absent.
+	Element is present.
L	Functional *ag* genes are lost.
P	Functional *ag*-encoded proteins are present.

(a) Infertile offspring prevents gene flow because if an organism is infertile, it can't spread its genes, enabling speciation.

(b) The genome gained a promoter, ag repeat sequences, and 3' UTR, which allowed functional ag genes to be created, allowing the cods to survive and reproduce in colder temperatures.

(d) If a species has functional ag genes, it can survive in habitats with lower average temperatures than a species without those genes.

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Q5218/12

BEGIN Question 5

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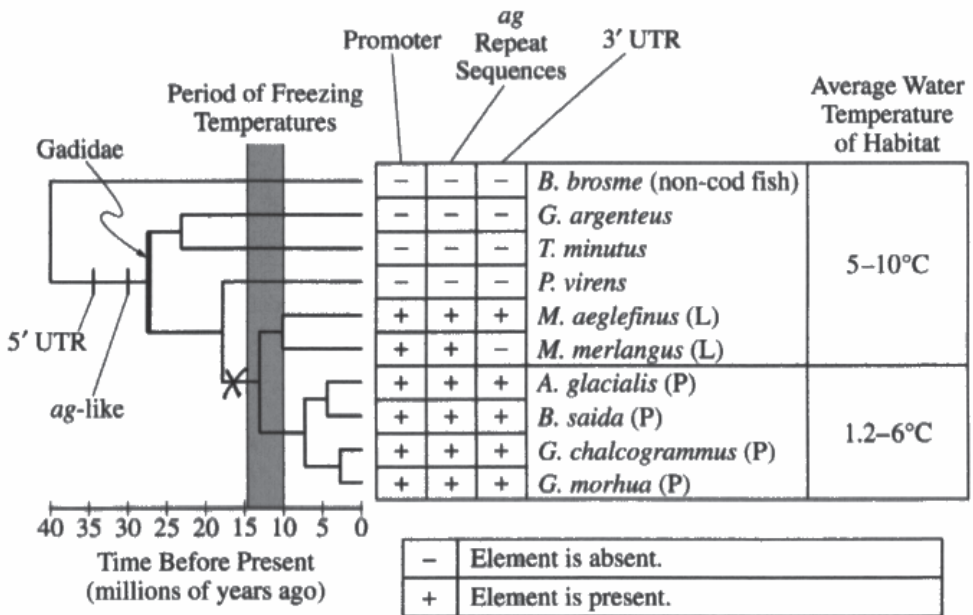

–	–	–	*B. brosme* (non-cod fish)	5–10°C
–	–	–	*G. argenteus*	
–	–	–	*T. minutus*	
–	–	–	*P. virens*	
+	+	+	*M. aeglefinus* (L)	
+	+	–	*M. merlangus* (L)	
+	+	+	*A. glacialis* (P)	1.2–6°C
+	+	+	*B. saida* (P)	
+	+	+	*G. chalcogrammus* (P)	
+	+	+	*G. morhua* (P)	

–	Element is absent.
+	Element is present.
L	Functional *ag* genes are lost.
P	Functional *ag*-encoded proteins are present.

the production of

a) Sterile, but viable offspring is a viable post-zygotic mechanism that prevents gene flow and enables speciation. This occurs when members of the same species coexist in similar areas, perhaps mate, but the offspring produced is unable to reproduce later on, hence preventing gene flow through generations.

b) The cods survived and reproduced after a period of freezing temperature as the fish that randomly had mutations for functional ag-encoded proteins had increased fitness and reproduced in the colder water, leading to only these fish continuing their gene flow, as evidenced by the A. glacilis, B saida, G. chalcogrammus, and G. morhua

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Additional page for answering Question 5

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still possessing these antifreeze proteins today.

d) Genetic differences among the species in the Gadidae family determine the habitats in which they can survive. Those fish with functional as-encoded proteins (A. glacialis, B. saida, G. chalcogrammus, and G. morhua) are able to survive and have higher fitness in cold-water so they like there. On the other hand, the rest of these fish don't possess these functional antifreeze proteins, causing them to best survive and reproduce in warmer waters.

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BEGIN Question 5

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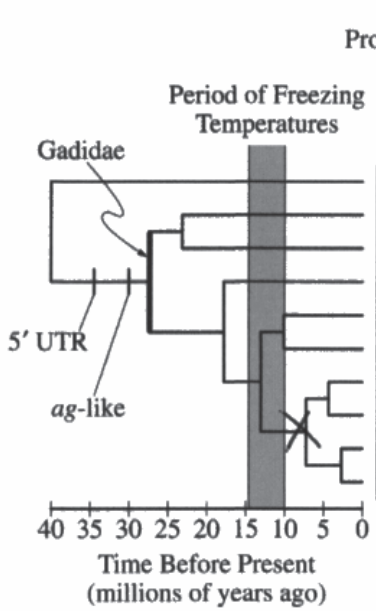

Promoter	ag Repeat Sequences	3′ UTR		Average Water Temperature of Habitat
–	–	–	*B. brosme* (non-cod fish)	5–10°C
–	–	–	*G. argenteus*	
–	–	–	*T. minutus*	
–	–	–	*P. virens*	
+	+	+	*M. aeglefinus* (L)	
+	+	–	*M. merlangus* (L)	
+	+	+	*A. glacialis* (P)	1.2–6°C
+	+	+	*B. saida* (P)	
+	+	+	*G. chalcogrammus* (P)	
+	+	+	*G. morhua* (P)	

–	Element is absent.
+	Element is present.
L	Functional *ag* genes are lost.
P	Functional *ag*-encoded proteins are present.

a) a mechanism that prevents gene flow is a lack of migration due to physical seperation. This means new ~~pp~~ populations or genes cannot interact with an existing population.

B) changes in genome allowed cods to survive and reproduce better by being able to survive in a larger range of temperatures. the changesin genomed allowed for cods to produce the AG protien that allows them to survive in colder temperatures, making them more "fit" in colder environments.

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Q5218/12

Additional page for answering Question 5

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D) Genetic differences in the Gadidae family determine the temperature of the habitats they live in. Species that have functional AG genes live in cold habitats between 1.2-6°C since they have the genes that allow them to survive there while those with a non-functioning AG gene or lacking the gene live in habitats with temps between 5-10°C because they don't have the anti-freeze protien

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Question 5

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

Overview

Question 5 presented a figure illustrating the basic structure of an *ag* gene, which encodes an antifreeze glycoprotein in the Gadidae, the cod family of fish. A second figure showed a phylogenetic tree illustrating the evolution of *ag* genes in ten species of fish as well as the average water temperature of the habitat in which each species is typically found.

Responses to part (a) were expected to describe a post-zygotic mechanism that prevents gene flow (Skill 1.A; LO EVO-3.F).

Responses to part (b) were expected to explain that the addition of regulatory elements (promoter, *ag* repeat sequence, 3′ untranslated region) to a non-coding region of the genome led to the development of functional genes that enabled cod to survive and reproduce after a period of freezing temperatures (Skill 2.B; LO EVO-3.A).

In part (c), responses were expected to represent the origin of the functional *ag* gene by marking the correct location on a template of the phylogenetic tree (Skill 2.D; LO EVO-3.B).

Responses to part (d) were expected to explain how genetic differences among species represented in the phylogenetic tree determine the habitats in which the species can survive (Skill 2.C; LO EVO-1.E).

Sample: 5A
Score: 4

The response earned 1 point in part (a) for describing "infertile offspring" as a post-zygotic mechanism that prevents gene flow and thus enables speciation. The response earned 1 point in part (b) for explaining that "The genome gained a promoter, ag repeat sequences, and 3′ UTR, which allowed functional ag genes" to emerge. The response earned 1 point in part (c) for placing an X on the colored L-shaped line on the phylogenetic tree to represent the origin of the functional *ag* gene. The response earned 1 point in part (d) for explaining that "if a species has functional ag genes, it can survive in habitats with lower average temperatures."

Sample: 5B
Score: 3

The response earned 1 point in part (a) for describing "the production of sterile, but viable offspring" as a post-zygotic mechanism that prevents gene flow and thus enables speciation. The response did not earn a point in part (b) because it does not explain how specific changes to the genome, such as addition of a promoter, led to the emergence of new functional genes or gene products. The response earned 1 point in part (c) for placing an X on the colored L-shaped line on the phylogenetic tree to represent the origin of the functional *ag* gene. The response earned 1 point in part (d) for explaining that "fish with functional ag-encoded proteins" are able to "survive…in colder waters."

Question 5 (continued)

Sample: 5C
Score: 1

The response did not earn a point in part (a) because it does not describe a post-zygotic mechanism that prevents speciation. The response did not earn a point in part (b) because while it explains the emergence of AG proteins, it does not explain the addition of the regulatory elements to the genome. The response did not earn a point in part (c) because the X was not placed in the location on the phylogenetic tree that represents the origin of the functional *ag* gene. The response earned 1 point in part (d) for explaining that "species that have functional AG genes live in cold habitats between 1.2-6 °C …while those with a non-functioning AG gene…live in habitats with temps between 5-10 °C ."