
AP Biology

Sample Student Responses and Scoring Commentary

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AP[®] BIOLOGY

2017 SCORING GUIDELINES

Question 3

Gibberellin is the primary plant hormone that promotes stem elongation. GA 3-beta-hydroxylase (GA3H) is the enzyme that catalyzes the reaction that converts a precursor of gibberellin to the active form of gibberellin. A mutation in the *GA3H* gene results in a short plant phenotype. When a pure-breeding tall plant is crossed with a pure-breeding short plant, all offspring in the F₁ generation are tall. When the F₁ plants are crossed with each other, 75 percent of the plants in the F₂ generation are tall and 25 percent of the plants are short.

		Second Base in Codon				
		U	C	A	G	
First Base in Codon	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop UGG Trp	U C A G
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Figure 1. The universal genetic code

- (a) The wild-type allele encodes a GA3H enzyme with alanine (Ala), a nonpolar amino acid, at position 229. The mutant allele encodes a GA3H enzyme with a threonine (Thr), a polar amino acid, at position 229. **Describe** the effect of the mutation on the enzyme and **provide reasoning** to support how this mutation results in a short plant phenotype in homozygous recessive plants. **(2 points)**

Description (1 point)	Reasoning (1 point)
The amino acid substitution changes the shape/structure/function of the protein.	The mutation decreases/eliminates gibberellin production.

- (b) Using the codon chart provided, **predict** the change in the codon sequence that resulted in the substitution of alanine for threonine at amino acid position 229. **(1 point)**

Prediction (1 point maximum)

- G ↔ A in the first position (of the codon)
- 5'-GCN-3' ↔ 5'-ACN-3'
- 5'-NGC-3' ↔ 5'-NGT-3' in the template strand of DNA

- (c) **Describe** how individuals with one (heterozygous) or two (homozygous) copies of the wild-type *GA3H* allele can have the same phenotype. **(1 point)**

Description (1 point)

- Enough active enzyme is produced from one wild-type/dominant allele.
- Enough gibberellin is produced in the presence of one wild-type/dominant allele.

3. Gibberellin is the primary plant hormone that promotes stem elongation. GA 3-beta-hydroxylase (GA3H) is the enzyme that catalyzes the reaction that converts a precursor of gibberellin to the active form of gibberellin. A mutation in the *GA3H* gene results in a short plant phenotype. When a pure-breeding tall plant is crossed with a pure-breeding short plant, all offspring in the F_1 generation are tall. When the F_1 plants are crossed with each other, 75 percent of the plants in the F_2 generation are tall and 25 percent of the plants are short.

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	UUC					U
	UUA	UCA } Leu	UCG } Ser	UAA } Stop	UGA } Stop	A
	UUG					U
C	CUU	CCU } Leu	CCC } Pro	CAU } His	CGU } Arg	C
	CUC					C
	CUA	CCA } Gln	CAG } Gln	CAA } Gln	CGA } Arg	A
	CUG					C
A	AUU	ACU } Ile	ACC } Thr	AAU } Asn	AGU } Ser	A
	AUC					A
	AUA	ACA } Met or Start	ACG } Met or Start	AAA } Lys	AGA } Arg	A
	AUG					A
G	GUU	GCU } Val	GCC } Ala	GAU } Asp	GGU } Gly	G
	GUC					G
	GUA	GCA } Glu	GAG } Glu	GAA } Glu	GGA } Gly	A
	GUG					G

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(a) The change from a nonpolar amino acid (Ala) to a polar amino acid (thr) disrupts the structure of the enzyme (tertiary structure). Because the molecule is non charged, weak interactions (such

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as van der Waals ~~interactions~~ interactions) will occur between the amino acid and other polar amino acids (will be attracted to each other, thus altering the folding of the protein). If the folding and twisting of the enzyme is changed, the active site will change and the precursor to gibberellin won't be able to bind and convert to the active form of gibberellin. This means that stem elongation will not be promoted due to decreased amounts of the active form of gibberellin.

b) GCA to ACA (replace first ~~nucleotide~~ ^{base} G with a A base).

c) The ~~G~~ wild-type GA3H could be dominant to the mutant allele, so the wild-type gene in a heterozygous plant could be expressed rather than the mutant gene. In a homozygous wild-type, the wild-type gene would be expressed as well. Both heterozygous and homozygous would be able to ^{convert} ~~produce~~ gibberellins to promote stem elongation, resulting in the same phenotype.

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3. Gibberellin is the primary plant hormone that promotes stem elongation. GA 3-beta-hydroxylase (GA3H) is the enzyme that catalyzes the reaction that converts a precursor of gibberellin to the active form of gibberellin. A mutation in the *GA3H* gene results in a short plant phenotype. When a pure-breeding tall plant is crossed with a pure-breeding short plant, all offspring in the F_1 generation are tall. When the F_1 plants are crossed with each other, 75 percent of the plants in the F_2 generation are tall and 25 percent of the plants are short.

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3a. This mutation would result in the enzyme not being able to catalyze the reaction that converts a precursor of gibberellin to the active form of gibberellin, so the mutation would ultimately

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result in a short plant phenotype. The enzyme's shape could be changed affecting its function since proteins work through induced fit. The order of codons and nucleotides affect the resulting protein.

3b. The first base in the codon changed ~~to an~~ a G to an A as a result of a point mutation.

3c. They can have the same phenotype if the ~~GAT~~ wild type GAT allele is completely dominant ~~over~~ ^{to} the recessive allele. The phenotype is the gene being represented physically or usually. Complete dominance is shown. The dominant allele is the one that is expressed over the recessive allele.

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PAGE FOR ANSWERING QUESTION 3

a. The mutation changes the amino acid sequence which alters the function of the enzyme it creates. The mutation altered a growth enzyme which then ~~affected~~ led

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b. short height being a ~~recessive~~ homozygous recessive phenotype.

b. Instead of producing Ala by having GC- for the codon, the mutated enzyme produced Thr which has AC- as its codon. So a substitution between G and A resulted in the mutation.

c. Tall plants are dominant over small plants ~~the~~ which means that Aa has both alleles, but expresses a tall phenotype because tall is dominant. So two plants could have the genotypes of Aa and AA, and still have the same phenotype of being tall.

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2017 SCORING COMMENTARY

Question 3

Overview

This question focused on the genetics behind the inheritance of stem growth in plants. Students were presented with a description of the role of the plant growth hormone gibberellin in stem elongation and an explanation of how the presence of GA3H, an enzyme, results in the biochemical synthesis of gibberellin. Students were then provided with a description of a cross between GA3H wild type and GA3H mutant plants and the outcome of the cross, as well as a description of a specific amino acid substitution that occurred in the GA3H mutant enzyme. Students were also supplied with a genetic code chart. Students were asked to describe the effect of the mutation on the enzyme and to provide reasoning to support the observed results from the cross. Then the students were asked to predict the change in the codon sequence that resulted in the change in the amino acid sequence of the enzyme. Students were also asked to describe how both individuals who are heterozygous and individuals who are homozygous for the wild type GA3H allele could have the same phenotype.

Sample: 3A

Score: 4

The response earned 1 point in part (a) for describing that the change in amino acid sequence disrupts the structure of the enzyme. The response earned 1 point in part (a) for providing reasoning that the enzyme won't be able to bind and convert gibberellin to the active form. The response earned 1 point in part (b) for predicting that the sequence changes from GCA to ACA. The response earned 1 point in part (c) for describing that the wild-type gene in a heterozygous plant could be expressed and would be able to convert gibberellins to promote stem elongation.

Sample: 3B

Score: 3

The response earned 1 point in part (a) for providing reasoning that the mutation would result in the enzyme not being able to catalyze the reaction that converts a precursor of gibberellin to the active form of gibberellin. The response earned 1 point in part (a) for describing that the enzyme's shape changed. The response earned 1 point in part (b) for predicting that the first base in the codon changed from a G to an A.

Sample: 3C

Score: 2

The response earned 1 point in part (a) for describing that the mutation alters the function of the enzyme. The response earned 1 point in part (b) for predicting that codon will change from a GC- to an AC-.