2019

AP® CollegeBoard

AP® Biology

Sample Student Responses and Scoring Commentary

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AP® BIOLOGY
2019 SCORING GUIDELINES

Question 1

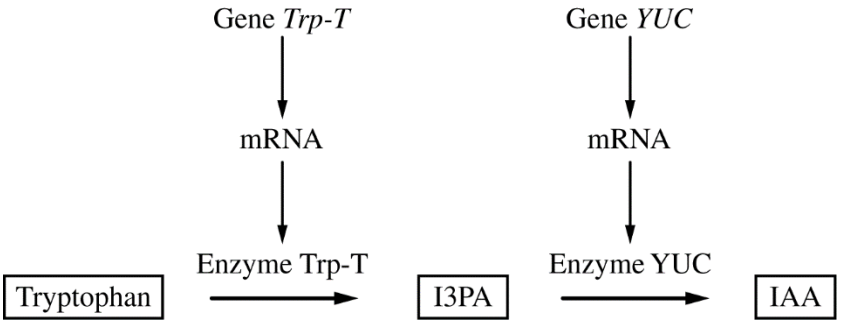

Figure 1. Model of two-step enzymatic plant pathway for synthesis of IAA from tryptophan

Auxins are plant hormones that coordinate several aspects of root growth and development. Indole-3-acetic acid (IAA) is an auxin that is usually synthesized from the amino acid tryptophan (Figure 1). Gene *Trp-T* encodes an enzyme that converts tryptophan to indole-3-pyruvic acid (I3PA), which is then converted to IAA by an enzyme encoded by the gene *YUC*.

(a) **Circle** ONE arrow that represents transcription on the template pathway. **Identify** the molecule that would be absent if enzyme YUC is nonfunctional.

Circle (1 point)

- Circle around either arrow pointing from a gene (*Trp-T* or *YUC*) to mRNA

Identification (1 point)

- IAA

(b) **Predict** how the deletion of one base pair in the fourth codon of the coding region of gene *Trp-T* would most likely affect the production of IAA. **Justify** your prediction.

Prediction (1 point)

- Reduction in IAA production OR No production of IAA

Justification (1 point)

- The mutation will result in the translation of an inactive/nonfunctional Trp-T enzyme.
- The mutation will result in no translation of the Trp-T enzyme.
- The mutation will result in no/reduced production of I3PA.

(c) **Explain** one feedback mechanism by which a cell could prevent production of too much IAA without limiting I3PA production.

Explanation (2 points)

- Negative feedback/feedback inhibition/increasing amounts of IAA inhibits the pathway.
- Production of YUC enzyme is inhibited OR YUC enzyme activity is inhibited.

Question 1 (continued)

(d) Rhizobacteria are a group of bacteria that live in nodules on plant roots. Rhizobacteria can produce IAA and convert atmospheric nitrogen into forms that can be used by plants. Plants release carbon-containing molecules into the nodules. Based on this information, **identify** the most likely ecological relationship between plants and rhizobacteria. **Describe** ONE advantage to the bacteria of producing IAA.

Identification (1 point)

- Mutualism

Description (1 point)

- Increases habitat/number of nodules for the rhizobacteria.
- The bacteria receive carbon/carbon-containing molecules (as a result of increased plant growth).

(e) A researcher removed a plant nodule and identified several "cheater" rhizobacteria that do not produce IAA or fix nitrogen. **Describe** the evolutionary advantage of being a bacterial cheater in a population composed predominantly of noncheater bacteria. Plants can adjust the amount of carbon-containing molecules released into nodules in response to the amount of nitrogen fixed in the nodule. **Predict** the change in the bacterial population that would cause the plant to reduce the amount of carbon-containing molecules provided to the nodule.

Description (1 point)

- Cheaters/bacteria that benefit without producing IAA/fixing nitrogen have more energy for reproduction.

Prediction (1 point)

- Decrease in the nitrogen-fixing/noncheater bacteria
- Decrease in the amount of nitrogen fixed (by bacteria)

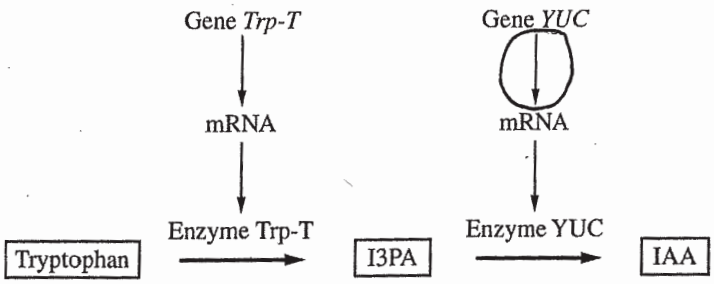

Figure 1. Model of two-step enzymatic plant pathway for synthesis of IAA from tryptophan

a) See diagram for circled arrow. If Enzyme YUC is nonfunctional, IAA will be absent.

b) The described deletion would likely significantly reduce IAA production. This is because a deletion of a base pair in a gene often causes a frame shift, which alters all subsequent codons in the gene. As the corresponding mRNA is translated, the altered codons append different amino acids than intended, resulting in a Trp-T Enzyme that is non-functional due to a differing primary structure.

c) To limit IAA production without limiting I3PA production, a cell would need a negative feedback loop that prevents Enzyme YUC availability in the presence of excess IAA. An example could consist of epigenetic markers produced in the presence of IAA that prevent transcription of the YUC gene, temporarily halting Enzyme YUC production.

d) The most likely ecological relationship between the plants & the rhizobacteria is mutualism. An advantage for the bacteria producing IAA is that the host roots will grow & develop in the presence of the IAA auxin, expanding the bacteria's habitat & ensuring the survival of the plant on which it depends.

e) Bacterial cheaters have an evolutionary advantage because they expend less energy

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

on producing IAA + fixing nitrogen than non-cheaters, giving them more energy to seek resources + reproduce and therefore increasing their fitness. Due to this advantage, the bacterial population will exhibit a hire cheating frequency in subsequent generations. This results in less nitrogen fixation in the plant's root nodules, which would cause the plant to reduce carbon compound release in response.

PAGE FOR ANSWERING QUESTION 1

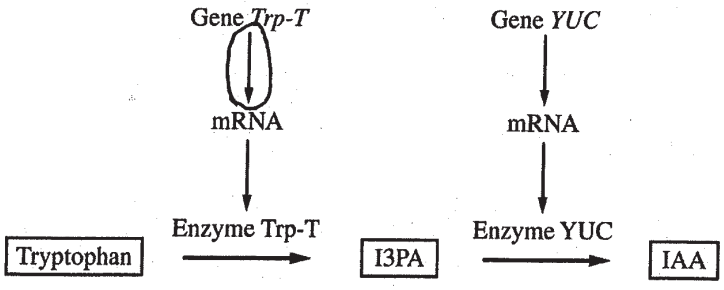

Figure 1. Model of two-step enzymatic plant pathway for synthesis of IAA from tryptophan

a.) The molecule that would be absent would be IAA.

b.) The deletion of one base pair could lead to the enzyme Trp-T to not be produced properly or at all b/c the deletion would affect the coding region of the gene, which would change the amino acid sequence, which would alter the protein that is produced after translation. IAA would not be produced b/c the Enzyme Trp-T would not be usable or produced, so tryptophan cannot become I3PA which cannot be converted to IAA.

c.) The cell could turn of the Gene YUC which would not create the Enzyme YUC which would mean I3PA could not be converted to IAA.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

d.) The most likely ecological relationship between the two is mutualistic. One advantage of the bacteria producing the IAA is that it helps keep the plant developing and growing which gives the bacteria more shelter and better chance of survivorship than if the plant were dying.

e.) The evolutionary advantage of the bacteria that "cheat" is that they do not have to expend energy to help the plants and just survive off of the carbon the plants give the bacteria, this would give the "cheaters" more energy to reproduce instead of helping the plants grow. The change in the bacterial population would be one where the bacteria are producing an insufficient amount of IAA, so the plants are not benefiting off of the bacteria anymore.

1C1

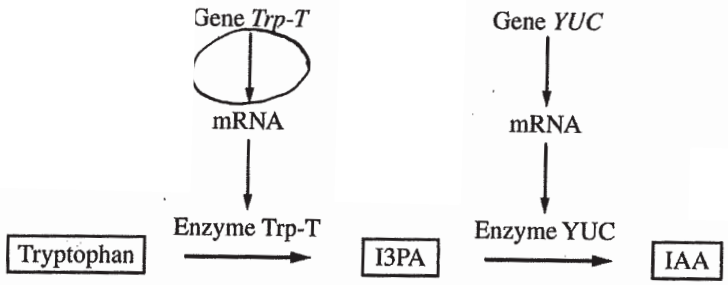

Figure 1. Model of two-step enzymatic plant pathway for synthesis of IAA from tryptophan

a) The molecule that would be absent if enzyme YUC is nonfunctional is indole-3-acetic acid (IAA).

b) The deletion of one base pair in the fourth codon of the coding region of gene Trp-T could stop the production of IAA. This is because a deletion of one base-pair can lead to a frameshift mutation, causing a different enzyme to probably be produced. If enzyme Trp-T is no longer produced by gene Trp-T, then I3PA cannot be made, which means nothing is available to be converted into IAA.

c) One feedback mechanism could be limiting the production of enzyme YUC. Without enough enzymes YUC, I3PA will not be able to be converted to IAA even if there are a lot of many of I3PA.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

d) Plants and Rhizobacteria most likely have a mutualistic relationship. One advantage of the bacteria producing IAA is that the IAA will coordinate aspects of root growth and development of the plant roots of the ~~there~~ plant that the rhizobacteria live in.

e) The evolutionary advantage of being a bacterial cheater in a population composed of noncheaters is that the cheater can have extra carbon intake but without doing work. The change in the bacterial population is that there will be more bacterial cheaters in the nodule.

AP® BIOLOGY
2019 SCORING COMMENTARY

Question 1

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

Overview

This question is based on a two-step enzymatic pathway in plants for the synthesis of the growth hormone indole-3-acetic acid (IAA) from the amino acid tryptophan. Students were provided with a model showing this pathway, including transcription and translation leading to production of the two enzymes needed for this pathway. The students were asked to interpret the model by circling an arrow on the diagram that represented the process of transcription and to identify the molecule that would be absent if one of the enzymes was nonfunctional. Students were then asked to apply concepts of gene mutation to predict the outcome of a specific mutation in the gene encoding one of the enzymes. The students were also asked to justify their prediction. Next, the students were asked to use their understanding of gene expression to explain a feedback mechanism that could lead to a reduction of one of the products of the pathway without affecting the production of an intermediate in the pathway. Students then considered ecological interactions involving populations of bacteria that live in root nodules of plants and produce IAA and fix nitrogen. Students were told that the plants release carbon-containing compounds into the nodule. Based on this information, students were asked to describe the type of symbiosis that occurs between the plant and bacterial species. Lastly, students were asked to describe the evolutionary advantage to "cheater" bacteria that did not produce IAA or fix nitrogen and to predict conditions in the bacterial population that would cause the plants to reduce the amount of carbon compounds released in the root nodules.

Sample: 1A
Score: 10

The response earned 1 point in part (a) for circling the arrow pointing from Gene *YUC* to mRNA. The response earned 1 point in part (a) for identifying that IAA would be absent. The response earned 1 point in part (b) for predicting that the deletion would "reduce IAA production." The response earned 1 point in part (b) for justifying that the deletion would result in a "Trp-T enzyme that is non-functional." The response earned 1 point in part (c) for explaining that a cell could limit IAA production with "a negative feedback loop." The response earned 1 point in part (c) for explaining that the feedback "prevents Enzyme YUC availability" and further clarifies that the feedback would "prevent transcription of the YUC gene, temporarily halting Enzyme YUC production." The response earned 1 point in part (d) for identifying that the ecological relationship is mutualism. The response earned 1 point in part (d) for describing that IAA would stimulate root growth, "expanding the bacteria's habitat." The response earned 1 point in part (e) for describing that bacterial cheaters "expend less energy on producing IAA & fixing nitrogen than non-cheaters, giving them more energy to … reproduce." The response earned 1 point in part (e) for predicting that "the bacterial population will exhibit a hire cheating frequency … This results in less nitrogen fixation."

Sample: 1B
Score: 8

The response earned 1 point in part (a) for circling the arrow pointing from Gene *Trp-T* to mRNA. The response earned 1 point in part (a) for identifying that the molecule that would be absent would be IAA. The response earned 1 point in part (b) for justifying that the deletion "could lead to the enzyme Trp-T to not be produced properly or at all." The response earned 1 point in part (b) for predicting that "IAA would not be produced." The response earned 1 point in part (c) for explaining that the feedback mechanism could "turn of the Gene YUC which would not create the Enzyme YUC." The response earned 1 point in part (d) for identifying that the relationship is mutualistic. The response earned 1 point in part (d) for describing that the plant "gives the

Question 1 (continued)

bacteria more shelter." The response earned 1 point in part (e) for describing that "the bacteria that 'cheat' … do not have to expend energy … this would give the 'cheaters' more energy to reproduce."

Sample: 1C
Score: 6

The response earned 1 point in part (a) for circling the arrow pointing from Gene *Trp-T* to mRNA. The response earned 1 point in part (a) for identifying that the molecule that would be absent is indole-3-acetic acid (IAA). The response earned 1 point in part (b) for predicting that the deletion could "stop the production of IAA." The response earned 1 point in part (b) for justifying that "[i]f enzyme Trp-T is no longer produced … then I3PA cannot be made." The response earned 1 point in part (c) for explaining that "[o]ne feedback mechanism could be limiting the production of enzyme YUC." The response earned 1 point in part (d) for identifying that "[p]lants and Rhizobacteria most likely have a mutualistic relationship."