2023

AP® Biology

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 4

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

Question 4: Conceptual Analysis — 4 points

Noncyclic electron flow and cyclic electron flow are two major pathways of the light-dependent reactions of photosynthesis. In noncyclic electron flow, electrons pass through photosystem II, then components of a chloroplast electron transport chain, and then photosystem I before finally reducing $NADP^+$ to NADPH. In cyclic electron flow, electrons cycle through photosystem I and some components of the electron transport chain (Figure 1).

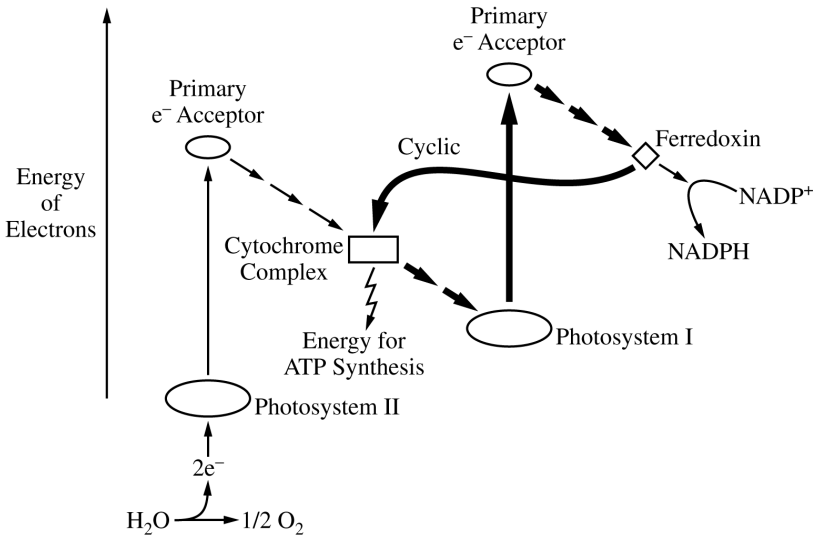

Figure 1. The pathways of noncyclic and cyclic (heavy arrows) electron flow. The cytochrome complex is a component of the electron transport chain between the two photosystems.

(a)	**Describe** the role of chlorophyll in the photosystems of plant cells. Accept one of the following: • Chlorophyll captures/absorbs light (energy). • Chlorophyll receives electrons (from water)/receives electrons (from an electron transport chain)/transfers electrons (to an electron transport chain).	**1 point**
(b)	Based on Figure 1, **explain** why an increase in the ratio of NADPH to $NADP^+$ will cause an increase in the flow of electrons through the cyclic pathway. • There is less/no $NADP^+$ to accept the electrons, so the electrons pass (instead) to the cyclic pathway/from ferredoxin to the cytochrome complex.	**1 point**
(c)	Using rice plants, scientists examined the effect of a mutation that results in the loss of the protein CRR6. CRR6 is a part of the photosystem I complex, and its absence reduces the activity of photosystem I. **Predict** the effect of the mutation on the rate of biomass (dry weight) accumulation. • The rate (of biomass accumulation)/Biomass/It will be lower (in comparison with plants without the mutation).	**1 point**
(d)	**Justify** your prediction in part (c). • There will be insufficient ATP/NADPH produced for the synthesis of carbohydrates/the Calvin cycle.	**1 point**
	Total for question 4	**4 points**

BEGIN Question 4

Begin your response to **QUESTION 4** on this page. Do not skip lines.

(a) Chlorophyll is a pigment in the photosystems of plant cells that absorb light, which is the source of energy that excites the photosystem's electrons and allow them to move to ~~higher~~ ~~energy~~ electron acceptors that carry the energy to other molecules.

(b) An increase in the ratio of NADPH to $NADP^+$ would increase cyclic electron flow because noncyclic electron flow creates more NADPH. If NADPH concentration is already high, it would inhibit noncyclic electron flow because there is not enough $NADP^+$ to accept the electrons, so the electrons will be transferred back to the electron transport chain ~~th~~ and photosystem I.

(c) The mutation of CRR6 would decrease the rate of biomass accumulation. (d) This is because less $NADP^+$ will be reduced, which is needed for the energy to carry out carbon fixation in the Calvin cycle that creates the sugars from CO_2 that contribute to the biomass of the plants.

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BEGIN Question 4

Begin your response to **QUESTION 4** on this page. Do not skip lines.

a) The chlorophyll absorb light energy ~~and~~ ~~ex~~ which excite electrons to begin the election transport chain.

b) An increase of the ratio will cause an increase in the flow of electrons through the cyclic pathway because ~~of a positive feedback mechanism~~. If more NADPH is being produced through the reduction of $NADP^+$, more electrons will go to the cyclic pathway after being ~~recycled~~ freed. through the reduction of $NADP^+$

c) There will be a decrease in ~~the~~ the rate of biomass accumulation

d) During the activity of photosystem I, NADPH and ATP are produced which are then used in the calvin cycle to provide energy for ~~to~~ which helps fixate carbon and create sugar. The sugar can be broken down for energy and increase the biomass of the plant or organism. Thus, if the photosystem I activity is decreased, then there will be less energy/products to help with the calvin cycle so less sugar will be made and less biomass will accumulate

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BEGIN Question 4

Begin your response to **QUESTION 4** on this page. Do not skip lines.

a.) Chlorophyll captures light to start the light-dependent reactions in Photosystem I and II.
b.) NADPH and NADP+ provide the electrons for the cyclic pathway, so an increase in their ratio will cause an increase in flow of electrons.
c.) The mutation will decrease biomass accumulation.
d.) Since the absence of CRR6 reduces activity in photosystem 1, photosynthesis will be less efficient or effective and causes less biomass to be produced.

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Question 4

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

Overview

This question presented a simplified model showing both noncyclic and cyclic electron flow in the light reactions of photosynthesis.

In part (a) students were expected to describe the role of chlorophyll in the photosystems of plant cells (Skill 1.A; Learning Objective [LO] ENE-1.J from the AP Biology Course and Exam Description [CED]).

In part (b) students were asked to explain why an increase in the ratio of NADPH to $NADP^+$ would cause an increased flow of electrons in the cyclic pathway (Skill 2.B; LO ENE-1.I).

Part (c) described a loss of function in the gene encoding CRR6, a component of photosystem I. Students were asked to predict the effect of this mutation on the rate of biomass accumulation in rice plants (Skill 6.E; LO ENE-1.J).

In part (d) students were expected to justify their prediction (Skill 6.C).

Sample: 4A
Score: 4

The response earned 1 point in part (a) by describing how chlorophyll absorbs light. The response earned 1 point in part (b) by explaining that the lower concentration of $NADP^+$ causes electrons to be passed to the cyclic pathway. The response earned 1 point in part (c) for predicting that biomass accumulation will decrease. The response earned 1 point in part (d) for justifying that the decrease in biomass occurs "because less $NADP^+$ will be reduced, which is needed for the energy to carry out carbon fixation in the Calvin cycle."

Sample: 4B
Score: 3

The response earned 1 point in part (a) for describing that chlorophyll absorbs light energy. The response did not earn a point in part (b) because it does not explain that there is less $NADP^+$. The response earned 1 point in part (c) for predicting that the rate of biomass accumulation will decrease. The response earned 1 point in part (d) for justifying that with insufficient NADPH and ATP the Calvin cycle will produce less sugar.

Sample: 4C
Score: 2

The response earned 1 point in part (a) for describing that chlorophyll "captures light." The response did not earn a point in part (b) because the explanation does not specify that there is less/no $NADP^+$, which would result in increased flow of electrons through the cyclic pathway. The response earned 1 point in part (c) because the response predicts a decrease in biomass accumulation. The response did not earn a point in part (d) because the response does not justify that there will be insufficient ATP/NADPH production, nor does it include a reference to diminished production of carbohydrates or reduction in the activity of the Calvin cycle.