2021 Digital Exam Practice

AP Biology

Scoring Materials for Digital Exam Practice

Please note: the digital exam practice resource was developed for students to complete technology checks, experience the digital platform, and practice answering exam questions, including each type of multiple-choice and free-response question they will encounter on exam day.

This digital exam practice is not a full-length exam, and it does not represent the complete scope of content and skills that students will see on the actual AP exam. This digital exam practice includes only content that would typically be taught in the first half of the school year, following the unit sequence in the AP Biology Course and Exam Description. For more information on the 2021 Exam format, please visit: apcentral.collegeboard.org/pdf/ap-2021-exam-formats.pdf

AP Exams are scored differently than traditional high school or college exams. When an AP Exam is administered, psychometric analysis determines the score ranges corresponding with each AP Exam score (5, 4, 3, 2, and 1) based on a composite score scale that combines and weights the different exam parts. Earning 40-50% of the available points can result in a score of 3 or better on many AP Exams. However, because the number of points corresponding with each AP Exam score can vary on different exams, students and teachers should not use the results of the digital exam practice to predict performance on the 2021 AP Exam.

Multiple-Choice Answer Key

Multiple-Choice Question	Answer
1	A
2	D
3	C
4	C
5	A
6	B
7	A
8	C
9	A
10	C
11	B
12	A
13	B
14	D

Question 1: Interpreting and Evaluating Experimental Results **9 points**

The red king crab, *Paralithodes camtschaticus*, inhabits shallow coastal waters in the northern Pacific Ocean that can vary in temperature from 1˚C to 13˚C. The body temperature of the crab is typically similar to that of the surrounding water. In order to study the effect of temperature on crab metabolism, scientists purified the enzyme phosphofructokinase (PFK) from red king crabs. PFK catalyzes a reaction early in the glycolysis pathway (Figure 1).

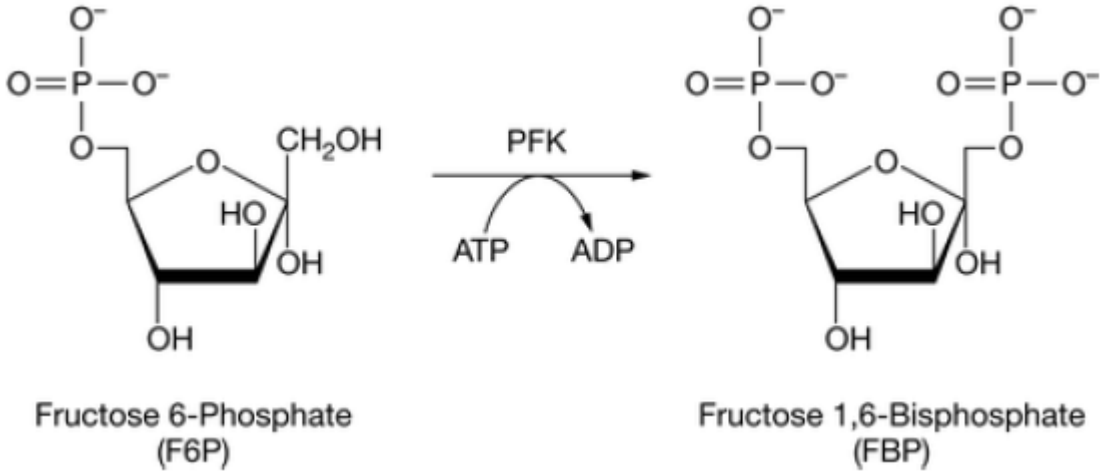


Figure 1. The conversion of fructose 6-phosphate (F6P) to fructose 1,6-bisphosphate (FBP) by PFK

The scientists determined the rate of the PFK-catalyzed reaction using a constant amount of PFK and increasing concentrations of the substrate F6P at 15˚C and 25˚C. To determine whether the reaction rate is affected by the nucleotide AMP, the analyses were additionally performed in the presence of 0.5 mM AMP. (Figure 2).

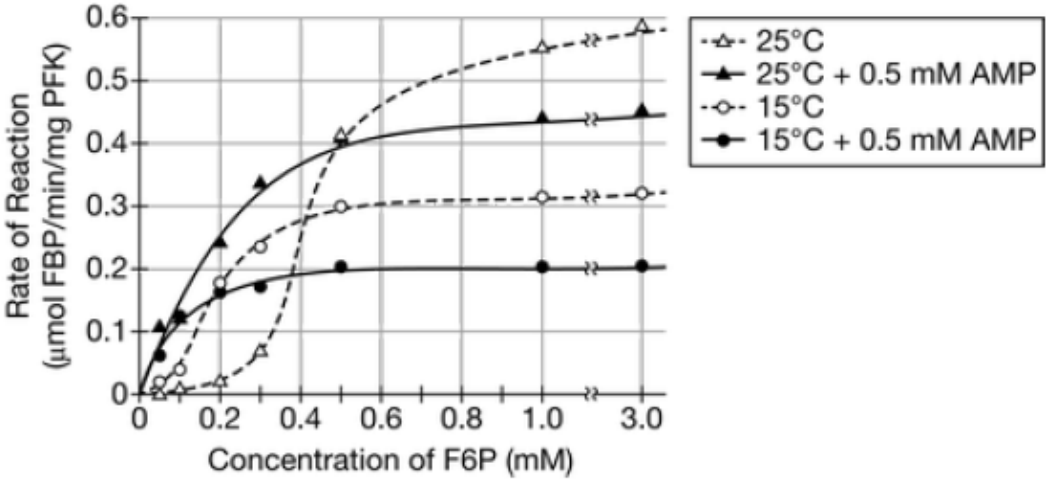


Figure 2. Effect of temperature and AMP on the rate of the reaction catalyzed by PFK

In a second analysis of PFK activity at different temperatures, the scientists determined how the concentration of citric acid in the reaction mixture affects the rate of the reaction at 5˚C, 15˚C, and 25˚C (Figure 3) in the presence of a constant amount of PFK. Citric acid is the first metabolic intermediate produced by the Krebs cycle. All reactions were performed in the presence of 1mM F6P and 0.5Mm AMP.

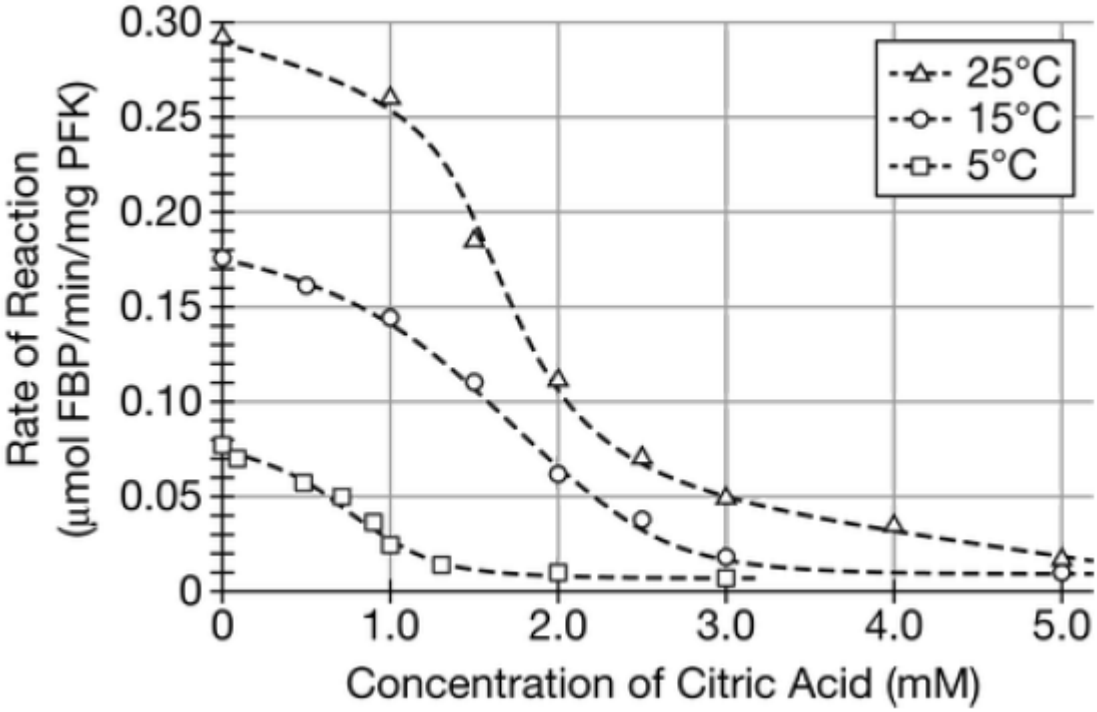


Figure 3. Effect of citric acid on the rate of the reaction catalyzed by PFK. All reactions were carried out in the presence of 1mM F6P and 0.5Mm AMP.

(a)	**Describe** the role of ATP in the reaction shown in Figure 1. • ATP provides both the phosphate group and the energy required to convert F6P to FBP.	1 point
(b)	**Identify** an independent variable in the experiment shown in Figure 2. Accept one of the following: • Temperature at which reaction was performed • Concentration of in the reaction mixture • Presence or absence of in the reaction mixture	1 point
	Justify the use of increasing concentrations of the substrate F6P when the scientists performed the experiments shown in Figure 2. • the scientists increased substrate concentration to determine the substrate concentration at which the reaction rate would reach a maximum/level off	1 point
(c)	Based on Figure 2, **describe** the effect of adding AMP to the reactions carried out at 15˚C. • Any given F6P concentration below 0.15mM (accept 0.1 mM – 0.2mM), the reaction rate is more rapid in the presence of AMP, whereas at any given F6P concentration above 0.15mM, the reaction rate is slower in the presence of AMP	1 point
	Based on Figure 3, **calculate** the fold increase in the reaction rate (how many times greater the reaction rate is) between the rate at 5˚C and at 25˚C in the presence of 2mM citric acid. • The fold increase in the reaction rate is calculated to be 11.	1 point
(d)	**State** the alternative hypothesis for the experiments shown in Figure 3. Accept one of the following: • Increasing concentration of citric acid causes a change (increase/decrease) in reaction rate. • The reaction rate changes (increases/decreases) at different temperatures	1 point

	The scientists claim that, in the absence of AMP, PFK of red king crabs functions efficiently at the crabs' typical low environmental temperatures because the active site of the enzyme can bind substrate more tightly at the low temperatures than it does at higher temperatures. **Support** the scientists' claim based on the data provided. • Support for the claim based on data that at low concentrations of substrate, the reaction rate is greater at 15°C (than at 25°C in the absence of AMP)	1 point
	Predict the effect on the rate of the reaction catalyzed by PFK in the experiment shown in Figure 2 if increasing concentrations of FBP are added to the reaction. • The reaction rate will decrease.	1 point
	When crustaceans such as crabs are kept in seawater with a lower-than-normal pH, ATP-requiring pumps that maintain ion gradients in the animals' bodies significantly increase their activity in comparison with normal levels. **Explain** how the increased use of ATP by these pumps will most likely affect the ability of the animals to carry out other metabolic reactions such as that catalyzed by PFK. • The rate of other metabolic reactions is likely to decrease because the cells have only so much ATP to use.	1 point
	Total for question 1	**9 points**

Question 2: Interpreting and Evaluating Experimental Results with a Graph and Error Bars **9 points**

Many types of cancer are treated with a combination of therapies. In lung cancer, some tumors respond well to the drug paclitaxel followed by radiation treatment. Paclitaxel is a chemical that disrupts mitosis. Instead of spindle fibers originating from the two sides (poles) of the cell, paclitaxel-treated cells develop three poles and then divide into three cells (tripolar division). Radiation therapy is more effective on tumor cells that have undergone tripolar division than on cells that have undergone normal mitosis.

Researchers treated cancer cells in the lab with different concentrations of paclitaxel for 15 hours. The researchers then determined the average percent of mitotic cells that were tripolar. The results are shown in Table 1.

TABLE 1. EFFECT OF PACLITAXEL CONCENTRATION ON PERCENT OF MITOTIC CELLS THAT WERE TRIPOLAR

Concentration of Paclitaxel (nM)	Average Percent of Mitotic Cells that were Tripolar ($\pm 2SE_{\bar{x}}$)
0	0.0 ± 0.0
2	17.0 ± 3.0
4	48.0 ± 3.5
6	65.0 ± 5.0
8	70.0 ± 4.0
10	50.0 ± 2.0

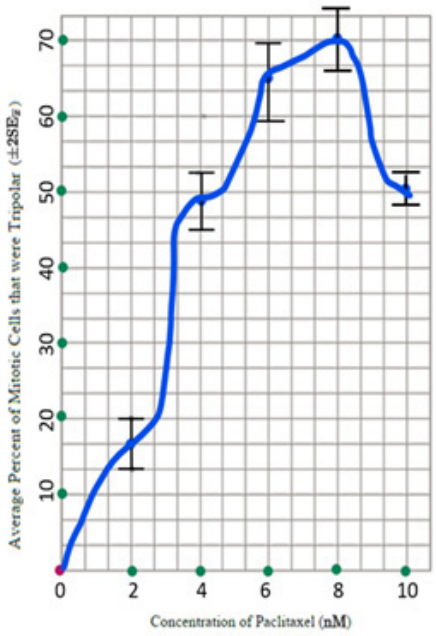


FIGURE 1. EFFECT OF PACLITAXEL CONCENTRATION ON PERCENT OF MITOTIC CELLS THAT WERE TRIPOLAR

The AURKA gene encodes an enzyme that helps assemble the spindle fibers, which signals the cells to continue through mitosis. When researchers analyzed the levels of AURKA protein in different types of cancer cells, they found that cancer cells expressing high levels of AURKA protein had more tripolar divisions when treated with paclitaxel, than did cancer cells expressing low levels of AURKA protein.

(a)	**Describe** the situations in which a normal human cell would enter the cell cycle and undergo mitotic cell division. • Cells divide by mitosis when the organism is growing or repairing tissues.	1 point
	Explain how spindle fibers help ensure the products of mitosis are two identical cells with a full set of chromosomes. • Spindle fibers attach to the center of each duplicated chromosome and assist in pulling one chromatid to each pole of the cells so that, when the cell divides, each daughter cells contains a copy of each chromosome	1 point
(b)	Based on the data, **determine** the concentration(s) of paclitaxel that is (are) most effective in causing tripolar cell division. • The concentration of paclitaxel that is most effective in causing tripolar cell division is between 6-8nM.	1 point
	Based on the data, **identify** the amount of paclitaxel that will allow for at least 60% of the cells to be tripolar. • 5.6nM of paclitaxel (between 5.4nM and 6.0nM)	1 point
	Describe the relationship between the concentration of paclitaxel (nM) and average percent of mitotic cells that were tripolar (+/-2SExbar) from 2nM to 6nM. • As the concentration of paclitaxel increases the average percentage of mitotic cells that were tripolar increases until 8nM.	1 point
(c)	Based on the data, **identify** the lowest level of paclitaxel that will allow for at least 50% of the cells to be tripolar. • 4nM is the lowest level of paclitaxel that will allow for at least of the cells to be tripolar	1 point
	From the start codon through the stop codon, the length of the fully processed AURKA mRNA is 1,212 nucleotides. **Calculate** the number of amino acids in the polypeptide chain coded for by the mRNA. • 403 amino acids are in the polypeptide chain coded for by AURKA mRNA	1 point
(d)	**Predict** the effect of a mutation that prevents the expression of AURKA on a normal (noncancerous) cell. • The cell will be unable undergo mitosis.	1 point
	Justify your prediction. • The cell will be unable to produce spindle fibers which are necessary for mitosis to occur.	1 point
	Total for question 2	**9 points**

Question 3: Scientific Investigation **4 points**

Cryptosporidium parvum (*C. parvum*) is a single-celled, eukaryotic parasite that infects human cells in the digestive system and causes illness.

Although it is a eukaryote, *C. parvum* does not have functional mitochondria and generates ATP only through glycolysis. *C. parvum* uses the enzyme lactate dehydrogenase to perform fermentation after glycolysis.

Two chemicals, gossypol and FX11, are noncompetitive inhibitors of lactate dehydrogenase. Researchers investigated the effectiveness of gossypol and FX11 as drugs to kill *C. parvum*. In the experiment, human cells were treated with different concentrations of either gossypol or FX11 after infection with *C. parvum*, and the relative growth of *C. parvum* compared with that of control cells was measured (Figures 1 and 2).

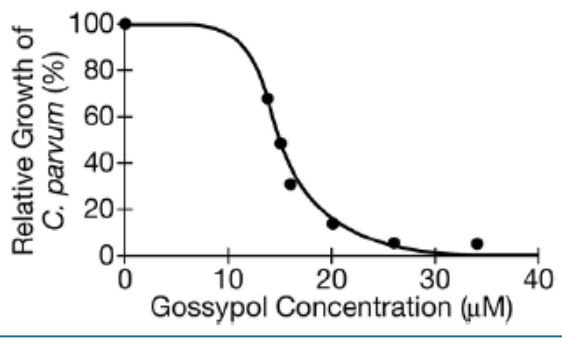


Figure 1. Effect of different concentrations of gossypol on *C. parvum* growth

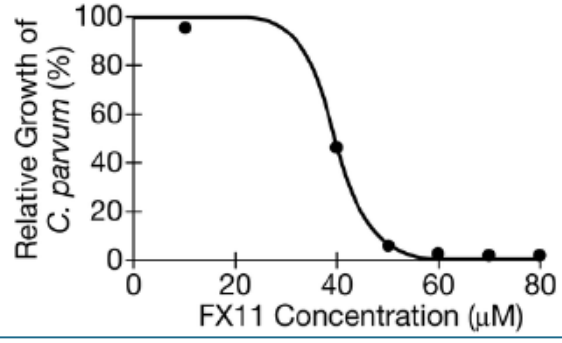


Figure 2. Effect of different concentrations of FX11 on *C. parvum* growth

(a)	**Describe** how *C. parvum* obtains the glucose it needs for glycolysis after it has infected another cell. • C. parvum absorbs glucose from its environment, which, in this case, takes glucose away from its host.	1 point
(b)	**Identify** the difference between the control cells and the experimental cells used in the experiment. • control cells are the same type of cells, infected with the parasite but not treated with any chemicals	1 point
(c)	Based on the data in Figure 1, **identify** the concentration of gossypol that reduced *C. parvum* growth to 50% of that in control cells. • the concentration of gossypol that reduced C. parvum growth to of that in control cells as 15 µM	1 point
(d)	Researchers discovered a strain of *C. parvum* that expresses a functional variation of the lactate dehydrogenase gene. A DNA sequence comparison showed that the variant differs from the normal sequence in the region that codes for the enzyme's allosteric site. **Predict** the effect of FX11 treatment on *C. parvum* cells that express this variant of lactase dehydrogenase. • FX11 will have little/no effect.	1 point
	Total for question 3	**4 points**

Question 4: Conceptual Analysis **4 points**

Solid tumors are clusters of cancer cells and often contain blood vessels. When molecule B binds to the wild-type Brec protein in the plasma membrane of certain solid tumor cancer cells (Figure 1), the cancer cells express the membrane protein A and sometimes stimulate increased growth of blood vessels into the tumors.

Cells with a particular mutation in the Brec gene (Brec-MUT cells) have much increased expression levels of A and stimulate greater growth of blood vessels than do cancer cells with the wild-type Brec (Brec-WT cells); the cells with the mutant Brec can trigger intracellular signaling in the absence of B.

Researchers proposed that the signaling pathway modeled in Figure 1 is triggered by activation of the wild-type Brec and is associated with phosphorylation and activation of kinase D, expression of A, and the ability of the cancer cells to stimulate blood vessel growth.

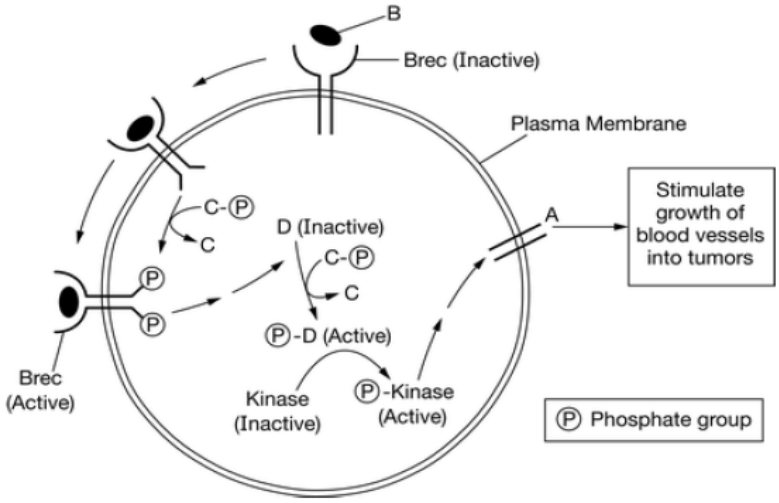


Figure 1. A simplified model of the normal signaling pathway hypothesized to play a role in certain cancer cells expressing A and stimulating blood vessel growth into solid tumors

(a)	Based on the signaling model shown in Figure 1, **describe** the role of molecule B. • Molecule B is the ligand/binds to the receptor and activates the receptor/signaling pathway.	1 point
(b)	**Explain** how the addition of a phosphate group to certain amino acids of Brec likely affects the tertiary structure and function of Brec. • The addition of a phosphate group could alter the structure and/or charge of Brec so that Brec can now interact with other signaling molecules in the cell	1 point
(c)	Based on the proposed signaling pathway, **predict** the relative amount of phosphorylated to unphosphorylated kinase in the cells when the cells are grown in nutrient broth lacking B. • There will be more unphosphorylated than phosphorylated kinase D.	1 point
(d)	**Justify** your prediction from **part c**. • Because the wild-type is inactive in the absence of Brec, the receptor will not stimulate intracellular signaling, and kinase D will remain unphosphorylated.	1 point
	Total for question 4	**4 points**

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

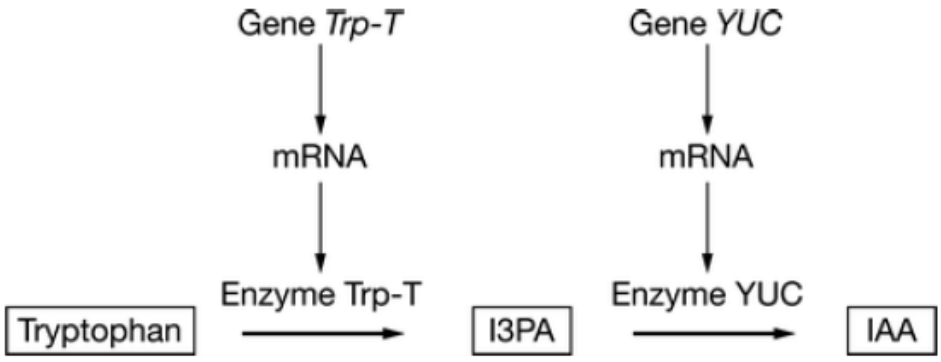


Figure 1. Model of two-step enzymatic plant pathway for synthesis of IAA from tryptophan

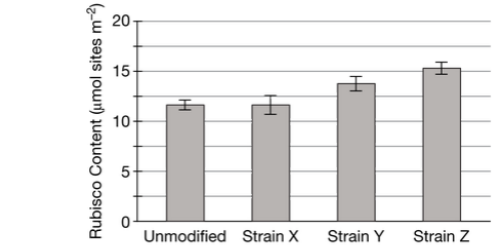
Auxins are plant hormones that coordinate several aspects of root growth and development. Indole-3-acetic acid (IAA) is an auxin that is usually synthesized from the amino acid tryptophan (Figure 1). Gene *Trp-T* encodes an enzyme that converts tryptophan to indole- -pyruvic acid (I3PA), which is then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

(a)	Based on Figure 1, **identify** the molecule that would be absent if enzyme YUC is nonfunctional. • IAA is the molecule that would be absent if enzyme YUC is nonfunctional.	1 point
(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. Accept one of the following: • A reduction in IAA production • No production of IAA	1 point
(c)	**Justify** your prediction from **part b**. Accept one of the following: • 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.	1 point
(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. **Describe** ONE advantage to the bacteria of producing IAA. Accept one of the following: • Producing IAA increases habitat for the rhizobacteria. • Producing IAA increases number of nodules for the rhizobacteria. • The bacteria receive carbon/carbon-containing molecules (as a result of increased plant growth).	1 point
	Total for question 5	**4 points**

Question 6: Analyze Data **4 points**

Increasing the efficiency of photosynthesis is one way to increase crop yield and help to feed human populations. One enzyme vital to the Calvin-Benson cycle of photosynthesis is Rubisco. Rubisco catalyzes the fixation of atmospheric CO_2 into organic molecules so that the carbon atoms can be used to produce carbohydrates. Rubisco is composed of two different types of polypeptide subunits: large subunits and small subunits. It is hypothesized that another protein called Rubisco assembly factor (RAF) is needed to help the polypeptide subunits fold together to form a functional enzyme.

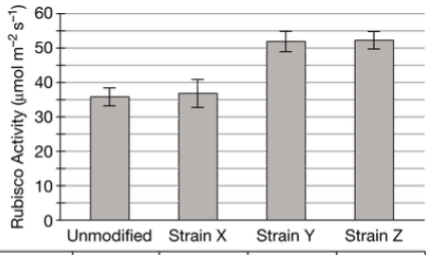
Researchers engineered three genetically modified strains of maize (corn). Strain X was modified to produce additional Rubisco polypeptides of both types in the cells. Strain Y was modified to produce additional protein. Strain was modified to produce both additional Rubisco polypeptides and additional protein. The Rubisco content of each of the maize strains studied is shown in Figure 1.



	Unmodified	Strain X	Strain Y	Strain Z
Additional Rubisco Polypeptides	–	+	–	+
Additional Rubisco Assembly Factor (RAF)	–	–	+	+

Figure 1. Rubisco content in genetically modified and unmodified strains of maize. (-) indicates unmodified levels of Rubisco polypeptides and/or RAF protein. (+) indicates additional Rubisco polypeptides and/or RAF protein.

The researchers then grew plants of each strain at a light intensity of 500 µmol of photons·m^{-2}·s^{-1} and a temperature of 25°C. After 40 days, the amount of Rubisco activity (as determined by the rate of carbon fixation) in each modified strain was determined (Figure 2).



	Unmodified	Strain X	Strain Y	Strain Z
Additional Rubisco Polypeptides	–	+	–	+
Additional Rubisco Assembly Factor (RAF)	–	–	+	+

Figure 2. Rubisco activity (in µmol of photons·m^{-2}·s^{-1}) in genetically modified and unmodified strains of maize. (-) indicates unmodified levels of Rubisco polypeptides and/or RAF protein. (+) indicates additional Rubisco polypeptides and/or RAF protein.

(a)	The small subunit of Rubisco is made up of many monomers. **Describe** the general structure of one of these monomers, including the characteristic that would allow it to interact with a positively charged monomer in a second Rubisco polypeptide. • that the monomers (amino acids) have an amino group, a carboxyl group, and a variable (R) group with a negative/partially negative charge.	1 point
(b)	**Identify** the strain of maize that served as the control group in the experiment whose data are shown in Figure 1. • The control group is the unmodified strain.	1 point
(c)	Researchers engineer a strain of maize with a mutation that results in a decrease in the expression of RAF. **Predict** the most likely effect of this RAF mutation on NADPH consumption in plants grown under the same conditions as those of the experimental strains. • NADPH consumption will be reduced.	1 point
(d)	Switchgrass is a grass species related to maize. A mutant strain of switchgrass has been found in which both types of Rubisco polypeptides are overexpressed; RAF expression is at normal levels. Using the experimental results shown in Figure 2, **explain** how the fitness of the mutant switchgrass will compare with that of nonmutant switchgrass. • The fitness of the switchgrass will not be affected by this mutation because the addition of Rubisco polypeptides alone does not increase Rubisco activity.	1 point
	Total for question 6	**4 points**