

BIOLOGY

SECTION I

14 Questions - Digital Practice Samples

1. Insulin is a protein hormone that is secreted in response to elevated blood glucose levels. When insulin binds to its receptors on liver cells, the activated receptors stimulate phosphorylation cascades that cause the translocation of glucose transporters to the plasma membrane.

Based on the information provided, which of the following best describes the role of insulin in this liver cell signal transduction pathway?

- A. It acts as a ligand.
- B. It acts as a receptor.
- C. It acts as a secondary messenger.
- D. It acts as a protein kinase.

2. The enzyme trypsin aids in protein digestion in the small intestine. The relative activity of trypsin at different pH values is shown in Figure 1.

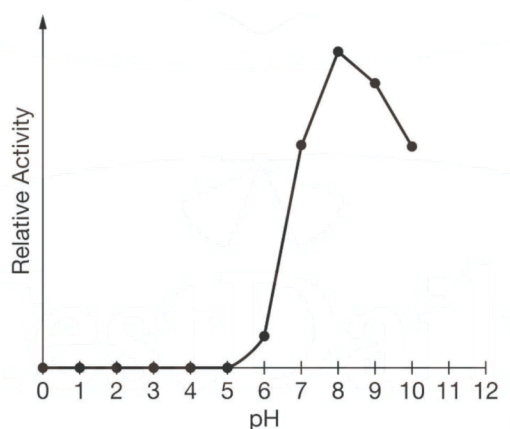


Figure 1. Effect of pH on the activity of trypsin

Which of the following statements best explains the activity levels of trypsin shown in Figure 1?

- A. The small intestine releases inhibitor molecules that block the activity of trypsin unless it is at its optimum pH.
- B. The number of effective collisions between trypsin and its substrate increase at higher pH values.
- C. As pH values increase, the substrate concentration decreases, leading to an eventual decline in the rate of the trypsin-catalyzed reaction.
- D. At extremely low pH values, trypsin is denatured and cannot function efficiently.

3. A student used a microscope to observe a wet-mount slide of red onion epidermal cells that were suspended in a 1% NaCl solution. The student then added a 15% NaCl solution to the slide and observed the changes that occurred. The student's observations are represented in Figure 1.

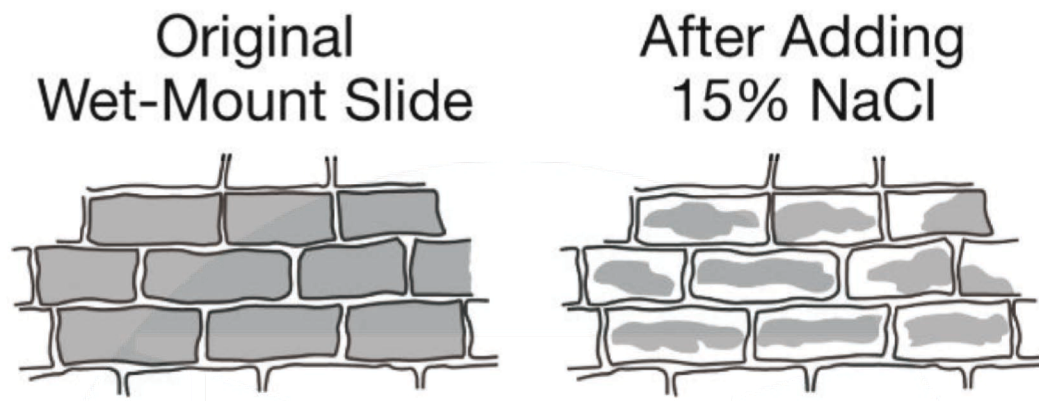


Figure 1. Student's observations of onion cells

Which of the following most directly explains the changes in the cells?

- A. The degradation of DNA in the nuclei of the cells
- B. The lysis of chloroplasts in the cells
- C. The movement of water from the central vacuoles of the cells into the solution
- D. The movement of NaCl from the solution into the cytoplasm of the cells

4. Scientists examined the folded structure of a purified protein resuspended in water and found that amino acids with nonpolar R groups were primarily buried in the middle of the protein, whereas amino acids with polar R groups were primarily on the surface of the protein.

Which of the following best explains the location of the amino acids in the folded protein?-

- A. Polar R groups on the surface of the protein can form ionic bonds with the charged ends of the water molecules.
- B. Polar R groups are too bulky to fit in the middle of the protein and are pushed toward the protein's surface.
- C. Nonpolar R groups that cannot form hydrogen bonds with water are pushed into the middle of the protein.
- D. Nonpolar R groups from different parts of the protein form covalent bonds with each other to maintain the protein's structure.

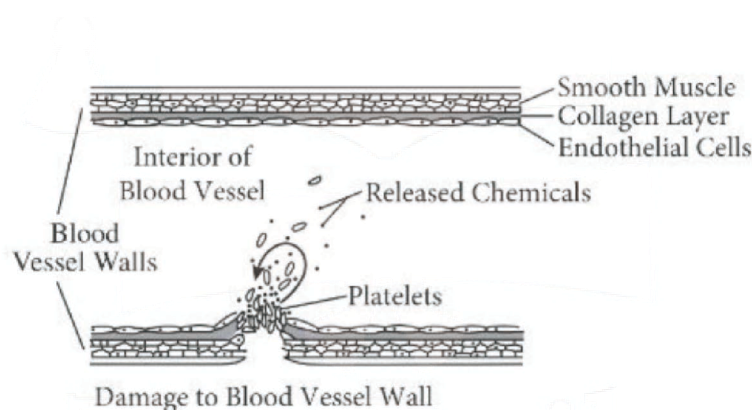


Figure 1. Formation of a platelet plug in a damaged blood vessel wall

5. Which of the following best explains the feedback mechanism illustrated in Figure 1?

- A. This is an example of positive feedback, because the few platelets that initially bind attract more platelets to the damaged area.
- B. This is an example of positive feedback, because it results from the interactions among collagen, endothelial cells, and platelets.
- C. This is an example of negative feedback, because a large clump of platelets can block the blood vessel and prevent blood flow through it.
- D. This is an example of negative feedback, because the accumulation of platelets returns the open blood vessel wall to a closed state.

6. It is estimated that oxygen production first evolved in photosynthetic prokaryotes approximately 2.7 billion years ago. The first photosynthetic prokaryotes are presumed to be similar to today's cyanobacteria.

Which of the following best supports the claim that photosynthetic prokaryotes were responsible for the oxygen in Earth's atmosphere?

- A. The light reactions of photosynthesis split carbon dioxide into carbon and oxygen.
- B. The light reactions of photosynthesis split water into hydrogen ions and oxygen.
- C. The Calvin cycle splits glucose into carbon, hydrogen, and oxygen.
- D. The Calvin cycle splits water into hydrogen ions and oxygen.

Questions 7 through 8 refer to the following material.

A student placed 20 tobacco seeds of the same species on moist paper towels in each of two petri dishes. Dish A was wrapped completely in an opaque cover to exclude all light. Dish B was not wrapped. The dishes were placed equidistant from a light source set to a cycle of 14 hours of light and 10 hours of dark. All other conditions were the same for both dishes. The dishes were examined after 7 days, and the opaque cover was permanently removed from dish A. Both dishes were returned to the light and examined again at 14 days. The following data were obtained.

Dish A

	Day 7 Covered	Day 14 Uncovered
Germinated Seeds	12	20
Green-leaved seedlings	0	14
Yellow-leaved seedlings	12	6
Mean stem length below first set of leaves	8mm	9mm

Dish B

	Day 7 Covered	Day 14 Uncovered
Germinated Seeds	20	20
Green-leaved seedlings	15	15
Yellow-leaved seedlings	5	5
Mean stem length below first set of leaves	3mm	3mm

7. According to the results of this experiment, germination of tobacco seeds during the first week is

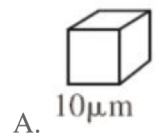
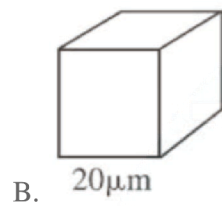
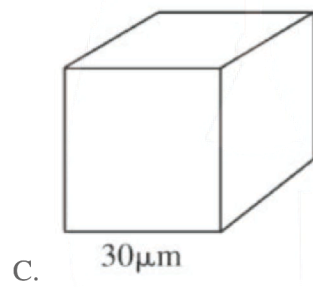
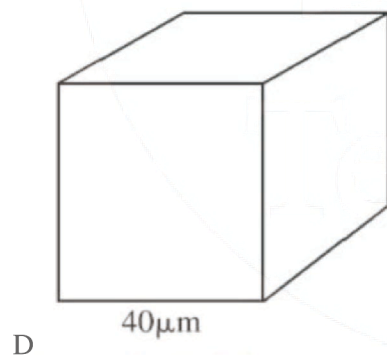
- A. increased by exposure to light
- B. unaffected by light intensity
- C. prevented by paper towels
- D. accelerated in green-leaved seedlings

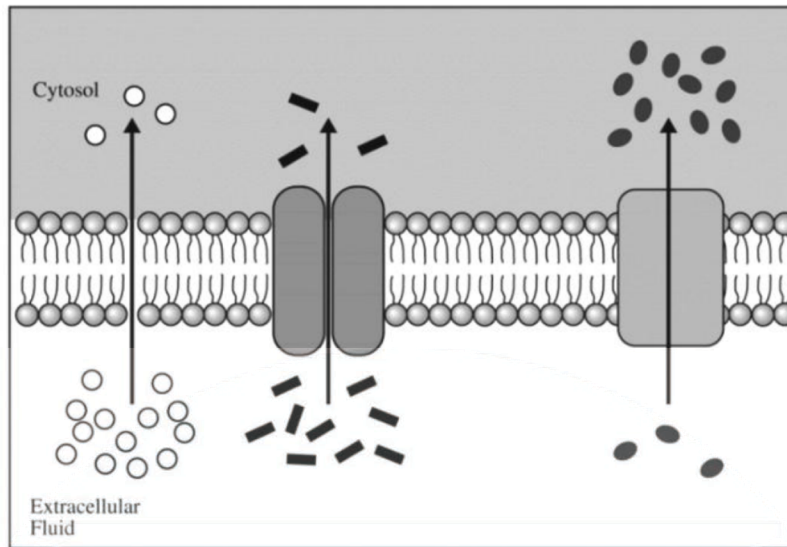
8. Additional observations were made on day 21, and no yellow-leaved seedlings were found alive in either dish. This is most likely because

- A. yellow-leaved seedlings were unable to absorb water from the paper towels
- B. taller green-leaved seedlings blocked the light and prevented photosynthesis
- C. yellow-leaved seedlings were unable to convert light energy to chemical energy
- D. a higher rate of respiration in yellow-leaved seedlings depleted their stored nutrients

9. Simple cuboidal epithelial cells line the ducts of certain human exocrine glands. Various materials are transported into or out of the cells by diffusion.

Which of the following cube-shaped cells would be most efficient in removing waste by diffusion?

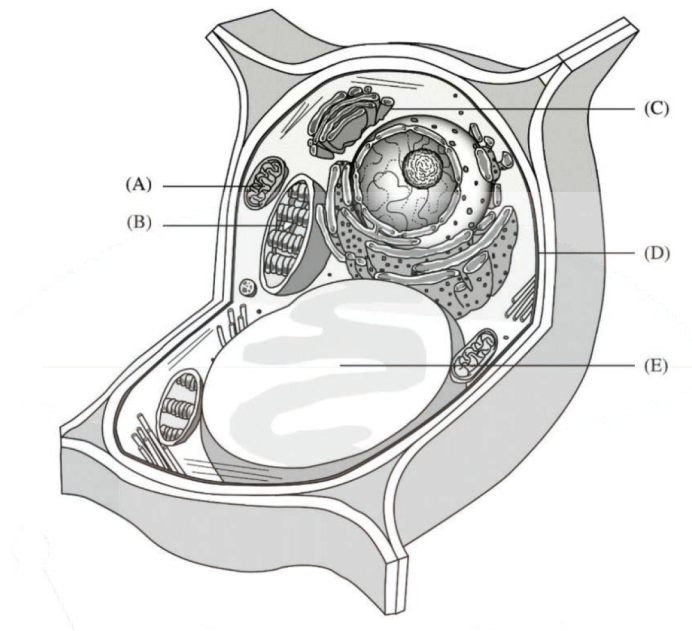




10. Which of the following scientific questions is most relevant to the model represented in the figure?

- A. Is ATP required for the transportation of sugars across the outer mitochondrial membrane?
- B. Do the types of phospholipids in a membrane affect the rate at which molecules enter a cell by passive diffusion?
- C. Which molecular substance is actively transported across the plasma membrane?
- D. How does temperature affect the movement of molecules into lysosomes?

Questions 11 through 13 refer to the following material.



11. Which of the labelled cellular structures evolved from a photoautotrophic prokaryote?

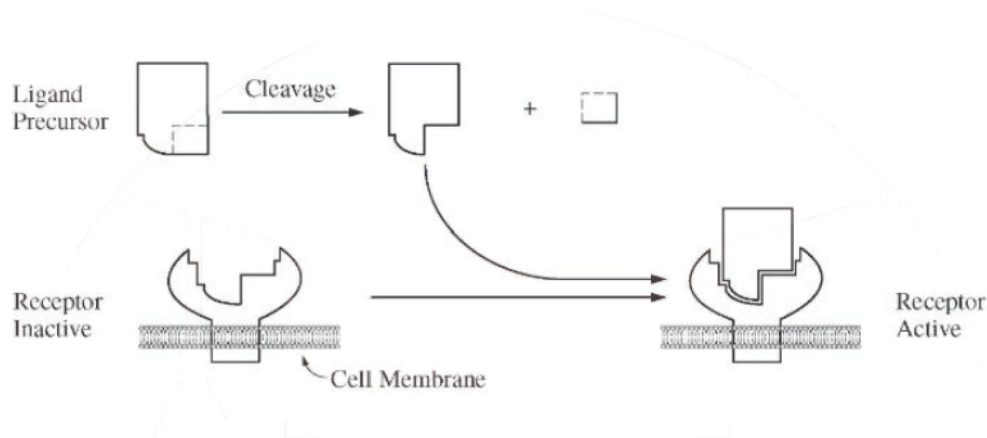
- A. A
- B. B
- C. C
- D. D

12. Which of the labelled cellular structures is the site of the conversion of chemical energy of glucose to ATP?

- A. A
- B. C
- C. D
- D. E

13. Which of the labelled cellular structures is the site of the modification and packaging of proteins and lipids prior to export from the cell?

- A. B
- B. C
- C. D
- D. E



14. The figure shows a model of a ligand precursor being cleaved to produce an active ligand that binds to a specific receptor. Which of the following is most likely to reduce the binding of the active ligand to its receptor?

- A. A change in the cytoskeletal attachment of transmembrane proteins
- B. The presence of a large amount of the precursor form of the ligand
- C. An increase in the ratio of the number of unsaturated to the number of saturated fatty acid tails of the membrane lipids
- D. A mutation in the receptor gene that causes a substitution of a charged amino acid for a nonpolar amino acid in the ligand binding site of the receptor

BIOLOGY

SECTION II

6 Questions - Digital Practice Samples

1. 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).

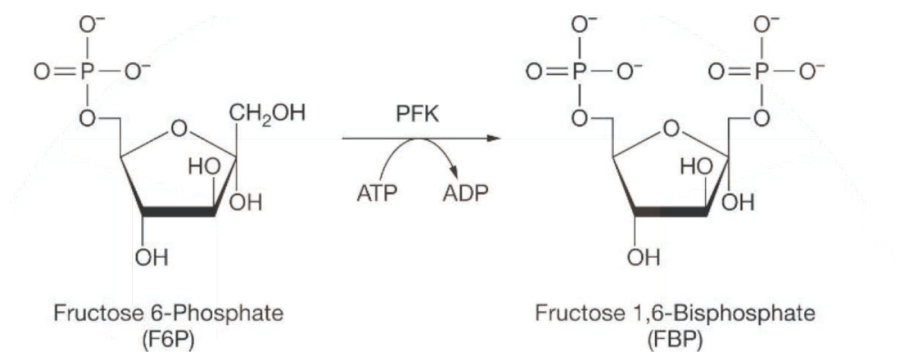


Figure 1. The conversion of fructose 6-phosphate (F6P) to fructose 1, 6-bisphosphate (FBP) by PFK

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).

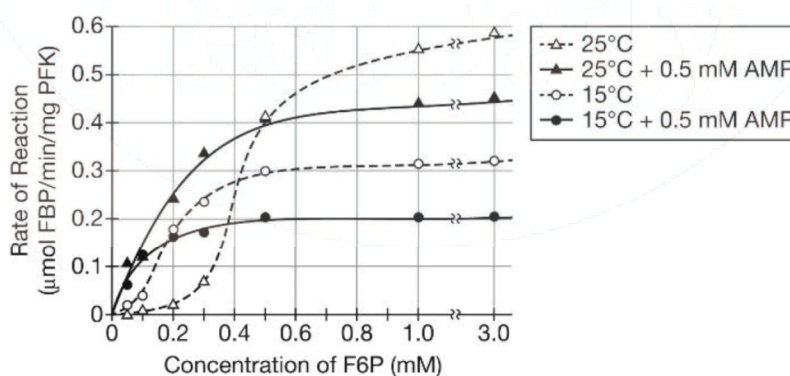


Figure 2. Effect of temperature and AMP on the rate of the reaction catalyzed by PFK

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 1 mM F6P and 0.5mM AMP.

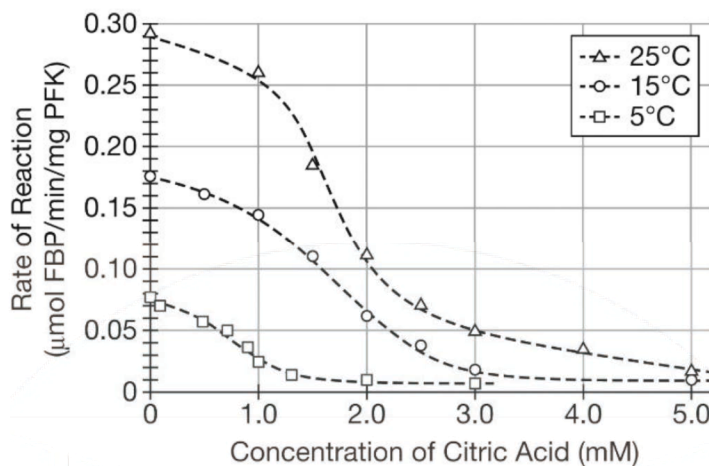


Figure 3. Effect of citric acid on the rate of the reaction catalyzed by PFK.

All reactions were carried out in the presence of 1 mM F6P and 0.5 mM AMP.

- Describe the role of ATP in the reaction shown in Figure 1.
- Identify an independent variable in the experiment shown in Figure 2. Justify the use of increasing concentrations of the substrate F6P when the scientists performed the experiments shown in Figure 2.
- Based on Figure 2, describe the effect of adding AMP to the reactions carried out at 15°C. 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 2 mM citric acid.
- State the alternative hypothesis for the experiments shown in Figure 3. 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. 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. 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.

2. 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($\pm 2SE_{\bar{y}}$)
0	0.0 $\pm$ 0.0
2	17.0 $\pm$ 3.0
4	48.0 $\pm$ 3.5
6	65.0 $\pm$ 5.0
8	70.0 $\pm$ 4.0
10	50.0 $\pm$ 2.0

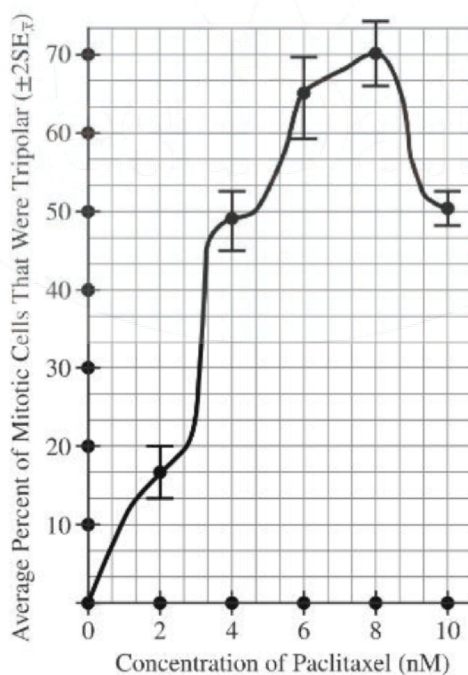


Figure 1. Effect of paclitaxel concentration on percent of mitotic cells that were tripolar

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. Explain how spindle fibers help ensure the products of mitosis are two identical cells with a full set of chromosomes.

b. Based on the data, determine the concentration(s) of paclitaxel that is (are) most effective in causing tripolar cell division. Based on the data, identify the amount of paclitaxel that will allow for at least 60% of the cells to be tripolar. Describe the relationship between the concentration of paclitaxel (nM) and average percent of mitotic cells that were tripolar (+2SE_x) from 2 nM to 6 nM.

c. Based on the data, identify the lowest level of paclitaxel that will allow for at least 50% of the cells to be tripolar. 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.

d. Predict the effect of a mutation that prevents the expression of AURKA on a normal

3. *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).

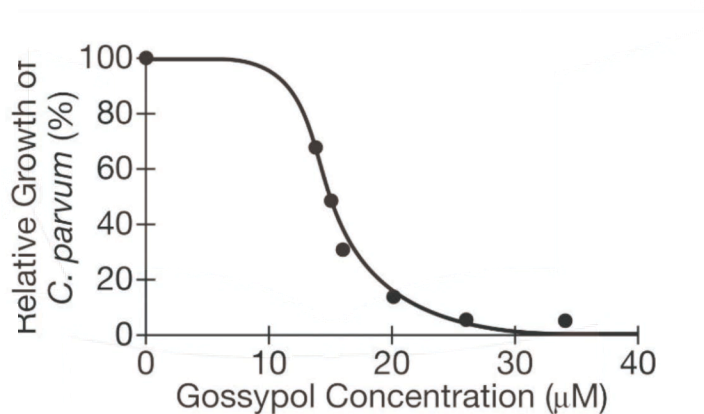


Figure 1. Effect of different concentrations of gossypol on *C. parvum* growth.

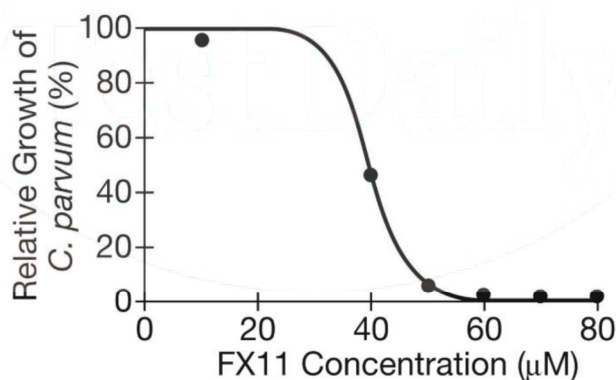


Figure 2. Effect of different concentrations of FX11 on *C. parvum* growth.

- Describe how *C. parvum* obtains the glucose it needs for glycolysis after it has infected another cell.
- Identify the difference between the control cells and the experimental cells used in the experiment.

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.

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 lactate dehydrogenase. Provide reasoning to support your prediction.

4. 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.

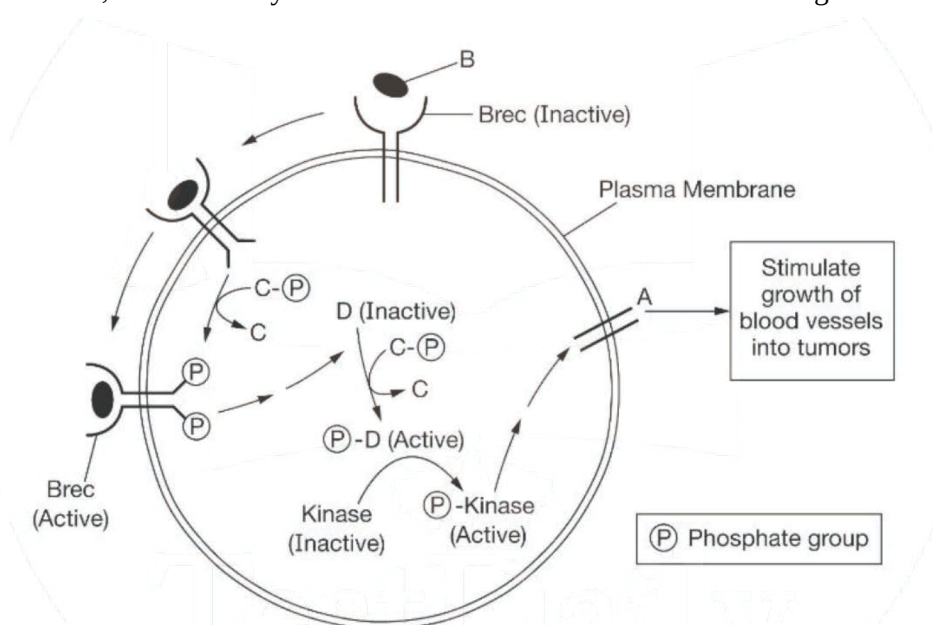


Figure 1. A simplified model of the normal signaling pathway hypothesized to play a role in certain cancer cells expressing A and stimulating blood vessel growth into solid tumors

- Based on the signaling model shown in Figure 1, describe the role of molecule B.
- Explain how the addition of a phosphate group to certain amino acids of Brec likely affects the tertiary structure and function of Brec.
- 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.
- Justify your prediction from part c.

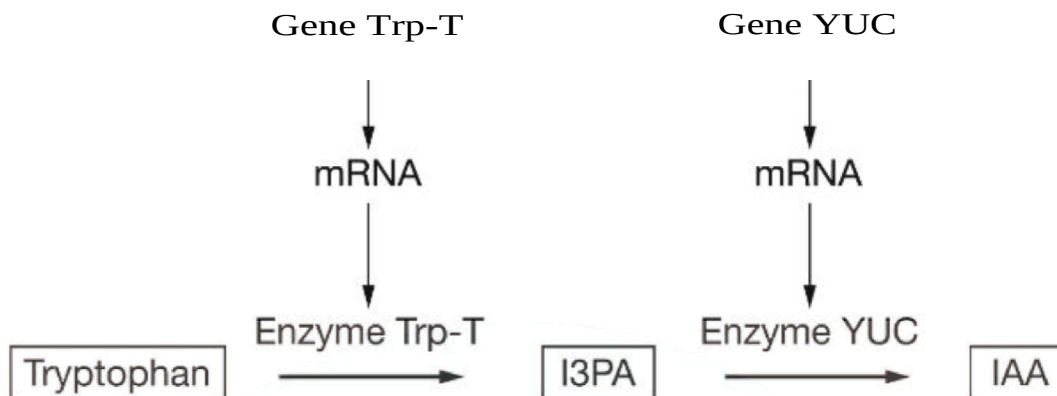


Figure 1. Model of two-step enzymatic plant pathway for synthesis of IAA from tryptophan

5. 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. Based on Figure 1, identify the molecule that would be absent if enzyme YUC is nonfunctional.

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.

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.

6. 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 CO₂ 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 Z 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.

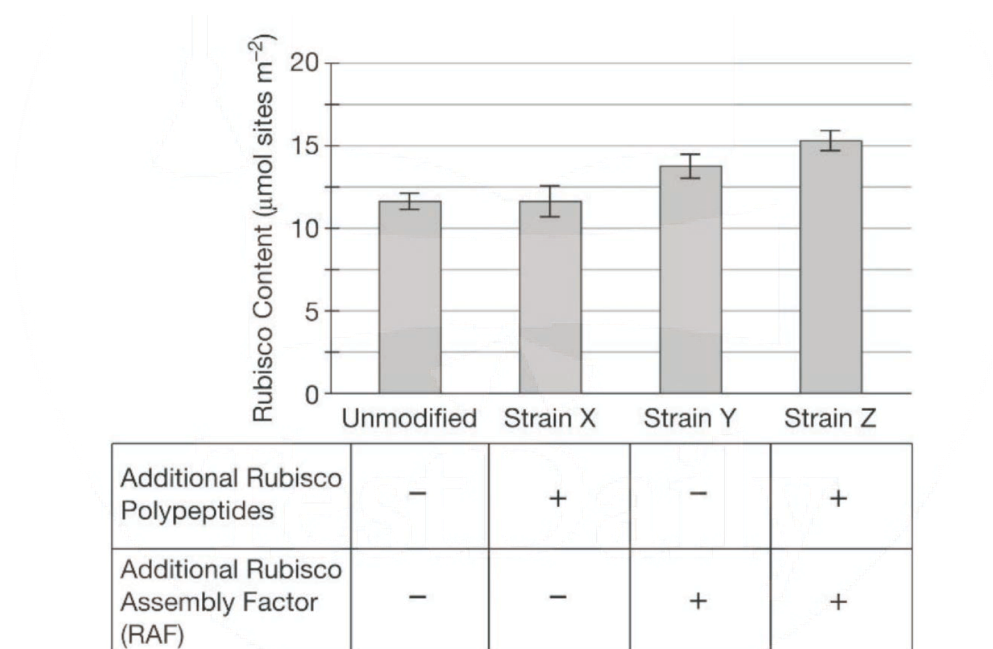


Figure 1. Rubisco content in genetically modified and unmodified strains of maize. (-) indicates unmodified levels of Rubisco polypeptides and/or RAF protein. (+) indicates additional Rubisco polypeptides and/or RAF protein.

The researchers then grew plants of each strain at a light intensity of 500 $\mu\text{mol of photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ 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).

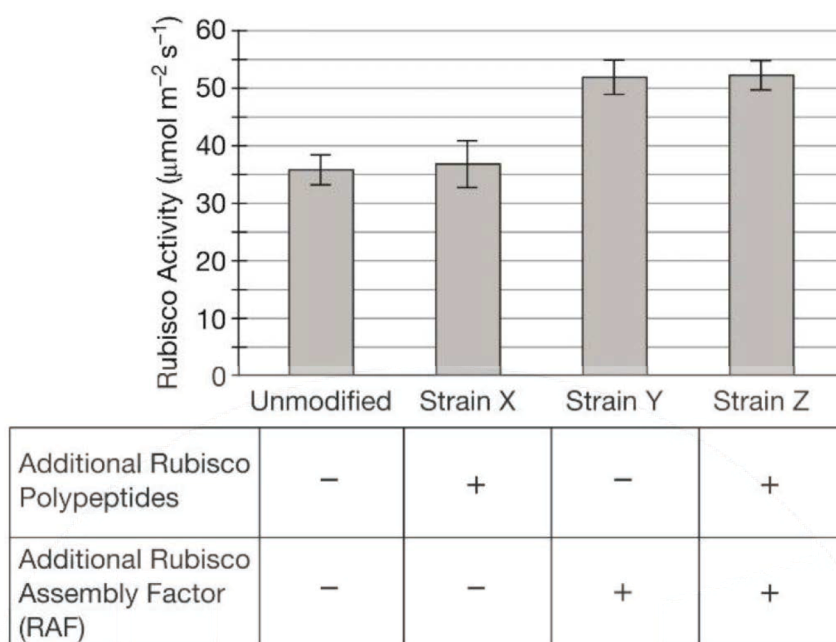


Figure 2. Rubisco activity (in $\mu\text{mol of photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$) in genetically modified and unmodified strains of maize. (-) indicates unmodified levels of Rubisco polypeptides and/or RAF protein. (+) indicates additional Rubisco polypeptides and/or RAF protein.

- 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.
- Identify the strain of maize that served as the control group in the experiment whose data are shown in Figure 1.
- 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.
- 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.

APPENDIX - ANSWERS

AP Biology 2021 - Digital Practice Samples

Matching answer key and scoring guidelines from the supplied exam source.

Digital practice samples: 14 multiple-choice and 6 free-response questions.

Question	Answer	Question	Answer	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 13: B. Diagram label C identifies the Golgi apparatus;
answer option B selects structure C. The separate explanation confused
the structure label with the answer letter. The matching scoring key is correct.
FRQ 6: the supplied stem omits the protein name in two strain descriptions;
the original accompanying figure identifies the additional protein as RAF.

AP Biology Digital Practice Scoring Guidelines

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).

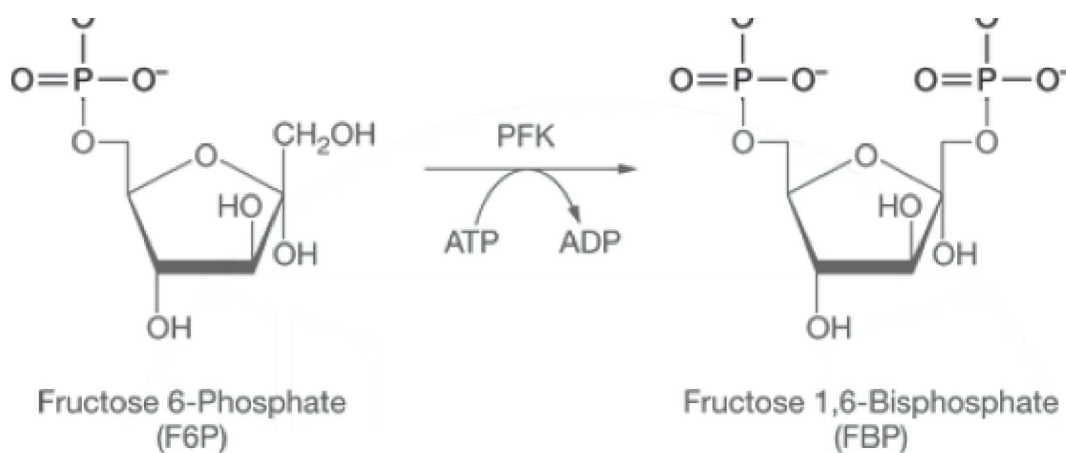


Figure 1. The conversion of fructose 6-phosphate (F6P) to fructose 1,6-bisphosphate (FBP) by PFK

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).

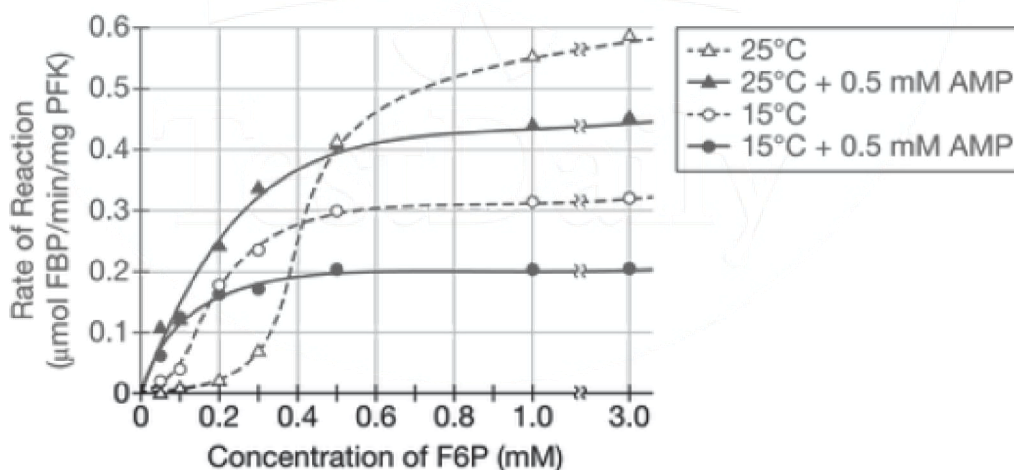


Figure 2. Effect of temperature and AMP on the rate of the reaction catalyzed by PFK

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.

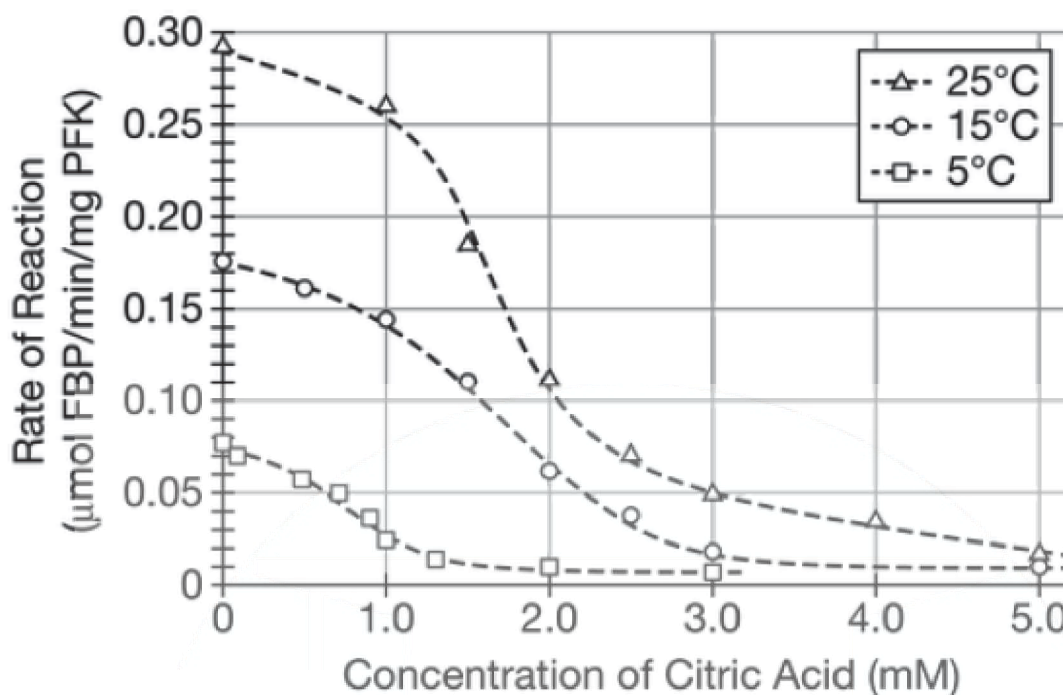


Figure 3. Effect of citric acid on the rate of the reaction catalyzed by PFK. All reactions were carried out in the presence of 1mM F6P and 0.5mM AMP.

- (a) Describe the role of ATP in the reaction shown in Figure 1. 1 point
- ATP provides both the phosphate group and the energy required to convert F6P to FBP.
- (b) Identify an independent variable in the experiment shown in Figure 2. 1 point
- 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
- Justify the use of increasing concentrations of the substrate F6P when the scientists performed the experiments shown in Figure 2. 1 point
- the scientists increased substrate concentration to determine the substrate concentration at which the reaction rate would reach a maximum/level off
- (c) Based on Figure 2, describe the effect of adding AMP to the reactions carried out at 15°C. 1 point
- 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
- 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. 1 point
- The fold increase in the reaction rate is calculated to be 11.
- (d) State the alternative hypothesis for the experiments shown in Figure 3. 1 point
- 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

AP Biology Digital Practice Scoring Guidelines

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. 1 point

- 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)

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. 1 point

- The reaction rate will decrease.

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. 1 point

- The rate of other metabolic reactions is likely to decrease because the cells have only so much ATP to use.

Total for question 1

9 points

AP Biology Digital Practice Scoring Guidelines

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.

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2	17.0 $\pm$ 3.0
4	48.0 $\pm$ 3.5
6	65.0 $\pm$ 5.0
8	70.0 $\pm$ 4.0
10	50.0 $\pm$ 2.0

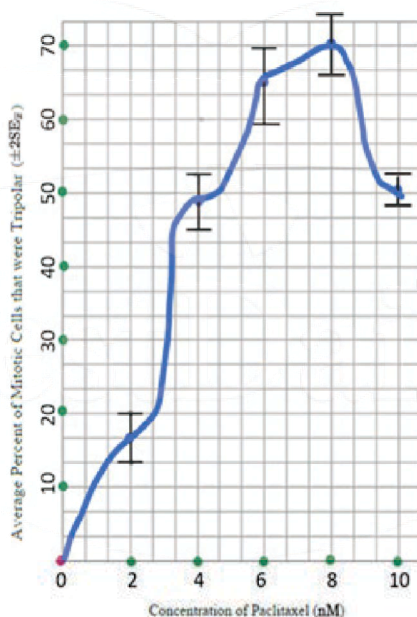


FIGURE 1. EFFECT OF PACLITAXEL CONCENTRATION ON PERCENT OF MITOTIC CELLS THAT WERE TRIPOLAR

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.

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- (a) Describe the situations in which a normal human cell would enter the cell cycle and undergo mitotic cell division. 1 point
- Cells divide by mitosis when the organism is growing or repairing tissues.
- Explain how spindle fibers help ensure the products of mitosis are two identical cells with a full set of chromosomes. 1 point
- 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
- (b) Based on the data, determine the concentration(s) of paclitaxel that is (are) most effective in causing tripolar cell division. 1 point
- The concentration of paclitaxel that is most effective in causing tripolar cell division is between 6-8nM.
- Based on the data, identify the amount of paclitaxel that will allow for at least 60% of the cells to be tripolar. 1 point
- 5.6nM of paclitaxel (between 5.4nM and 6.0nM)
- Describe the relationship between the concentration of paclitaxel (nM) and average percent of mitotic cells that were tripolar ($\pm 2SE_{\text{bar}}$) from 2nM to 6nM. 1 point
- As the concentration of paclitaxel increases the average percentage of mitotic cells that were tripolar increases until 8nM.
- (c) Based on the data, identify the lowest level of paclitaxel that will allow for at least 50% of the cells to be tripolar. 1 point
- 4nM is the lowest level of paclitaxel that will allow for at least of the cells to be tripolar
- 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. 1 point
- 403 amino acids are in the polypeptide chain coded for by AURKA mRNA
- (d) Predict the effect of a mutation that prevents the expression of AURKA on a normal (noncancerous) cell. 1 point
- The cell will be unable undergo mitosis.
- Justify your prediction. 1 point
- The cell will be unable to produce spindle fibers which are necessary for mitosis to occur.
- Total for question 2 9 points

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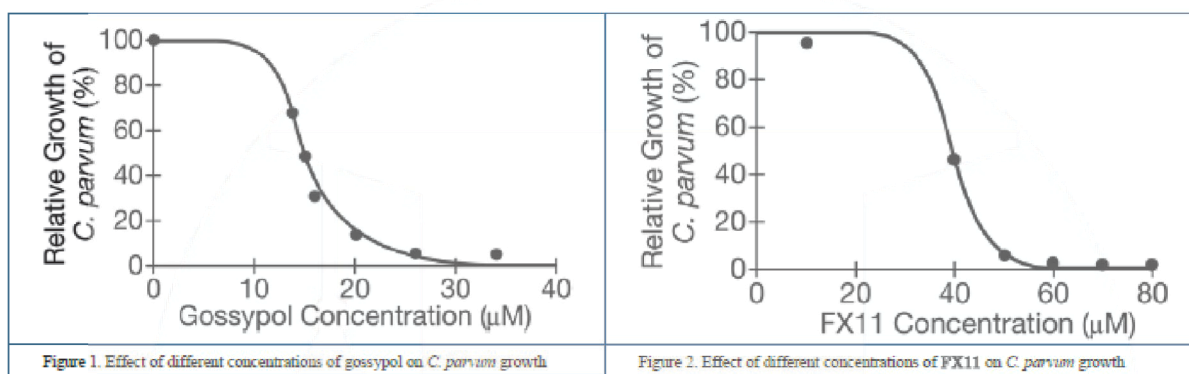
Question 3: Scientific Investigation

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).



- (a) Describe how *C. parvum* obtains the glucose it needs for glycolysis after it has infected another cell. 1 point
- *C. parvum* absorbs glucose from its environment, which, in this case, takes glucose away from its host.
- (b) Identify the difference between the control cells and the experimental cells used in the experiment. 1 point
- control cells are the same type of cells, infected with the parasite but not treated with any chemicals
- (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. 1 point
- the concentration of gossypol that reduced *C. parvum* growth to 50% of that in control cells as 15 μM
- (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 lactate dehydrogenase. 1 point
- FX11 will have little/no effect.

Total for question 3

4 points

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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.

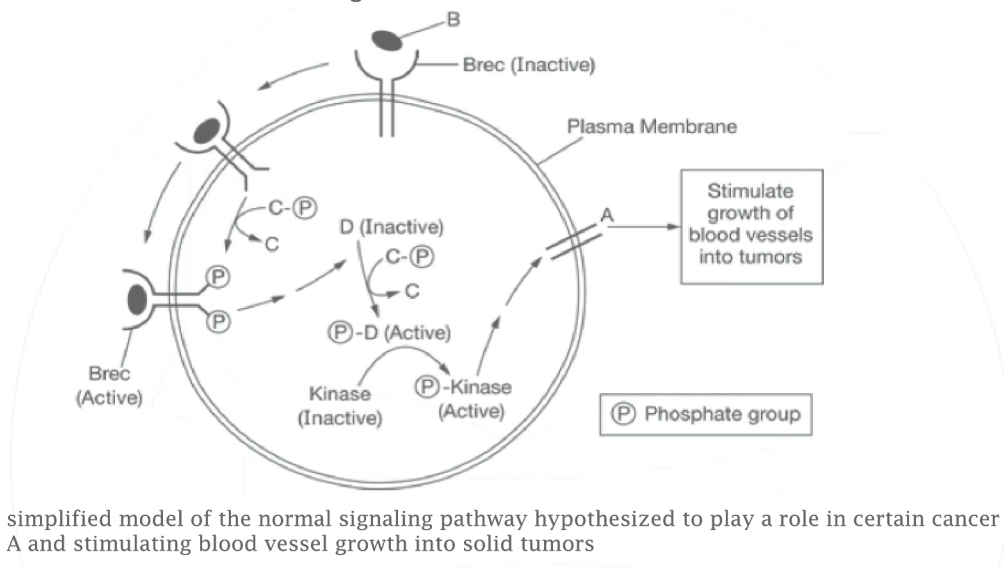


Figure 1. A simplified model of the normal signaling pathway hypothesized to play a role in certain cancer cells expressing A and stimulating blood vessel growth into solid tumors

- (a) Based on the signaling model shown in Figure 1, describe the role of molecule B. 1 point
- Molecule B is the ligand/binds to the receptor and activates the receptor/signaling pathway.
- Explain how the addition of a phosphate group to certain amino acids of Brec likely affects the tertiary structure and function of Brec. 1 point
- 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
- (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. 1 point
- There will be more unphosphorylated than phosphorylated kinase D.
- (d) Justify your prediction from part c. 1 point
- Because the wild-type is inactive in the absence of Brec, the receptor will not stimulate intracellular signaling, and kinase D will remain unphosphorylated.

Total for question 4

4 points

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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-3-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. 1 point
- IAA is the molecule that would be absent if enzyme YUC is nonfunctional.
- (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. 1 point
- Accept one of the following:
- A reduction in IAA production
 - No production of IAA
- (c) Justify your prediction from part b. 1 point
- 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.
- (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. 1 point
- 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).

Total for question 5

4 points

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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 CO₂ 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 Z 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.

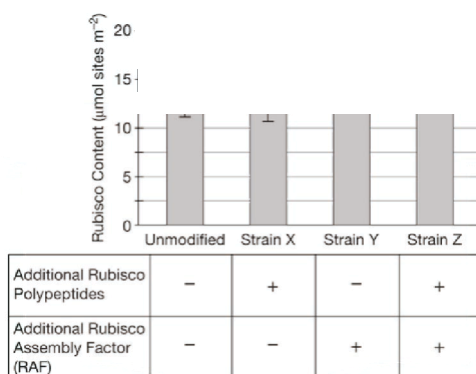


Figure 1. Rubisco content in genetically modified and unmodified strains of maize. (-) indicates unmodified levels of Rubisco polypeptides and/or RAF protein. (+) indicates additional Rubisco polypeptides and/or RAF protein.

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).

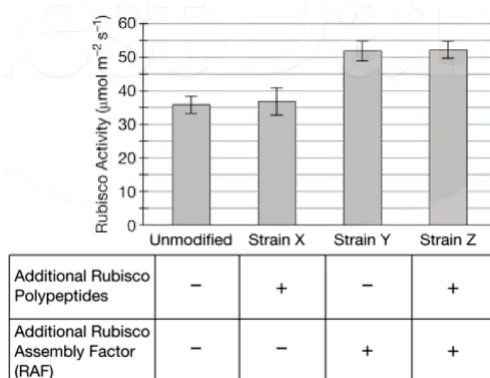


Figure 2. Rubisco activity (in μmol of photons·m⁻²·s⁻¹) in genetically modified and unmodified strains of maize. (-) indicates unmodified levels of Rubisco polypeptides and/or RAF protein. (+) indicates additional Rubisco polypeptides and/or RAF protein.

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- (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. 1 point
- that the monomers (amino acids) have an amino group, a carboxyl group, and a variable (R) group with a negative/partially negative charge.
- (b) Identify the strain of maize that served as the control group in the experiment whose data are shown in Figure 1. 1 point
- The control group is the unmodified strain.
- (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. 1 point
- NADPH consumption will be reduced.
- (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. 1 point
- The fitness of the switchgrass will not be affected by this mutation because the addition of Rubisco polypeptides alone does not increase Rubisco activity.

Total for question 6

4 points