5.1 Photosynthesis: An Introduction

Textbook pp. 212–218

Vocabulary

photoautotroph
light-dependent reactions
Calvin cycle
primary electron acceptor
antenna complex
reaction centre
absorption spectrum
action spectrum
photosystem I
photosystem II

MAIN IDEA: Producers use photosynthesis to convert light energy into chemical potential energy. Producers and consumers both use the chemical potential energy in these molecules to perform metabolism. Photosynthesis has two stages: the light-dependent reactions and the Calvin cylce.

1. (a) What is a photoautotroph?

   (b) Is a fern an example of a photoautotroph? Explain your answer. K/U T/I

2. State the main products of the light-dependent reactions. K/U

3. Suggest reasons why photosynthesis does not end immediately after the light-dependent reactions. K/U T/I

4. Why is it *not* accurate to describe the Calvin cycle as the dark reactions? K/U T/I

MAIN IDEA: The light-dependent reactions take place in the thylakoid membranes of the chloroplasts. Energy captured during the light-dependent reactions is used to synthesize NADPH and ATP.

STUDY TIP

Reviewing Work
Review the roles and interactions of ATP and $NADP^+$ in Chapter 4.

5. Label the parts of the chloroplast, shown in **Figure 1** below. K/U

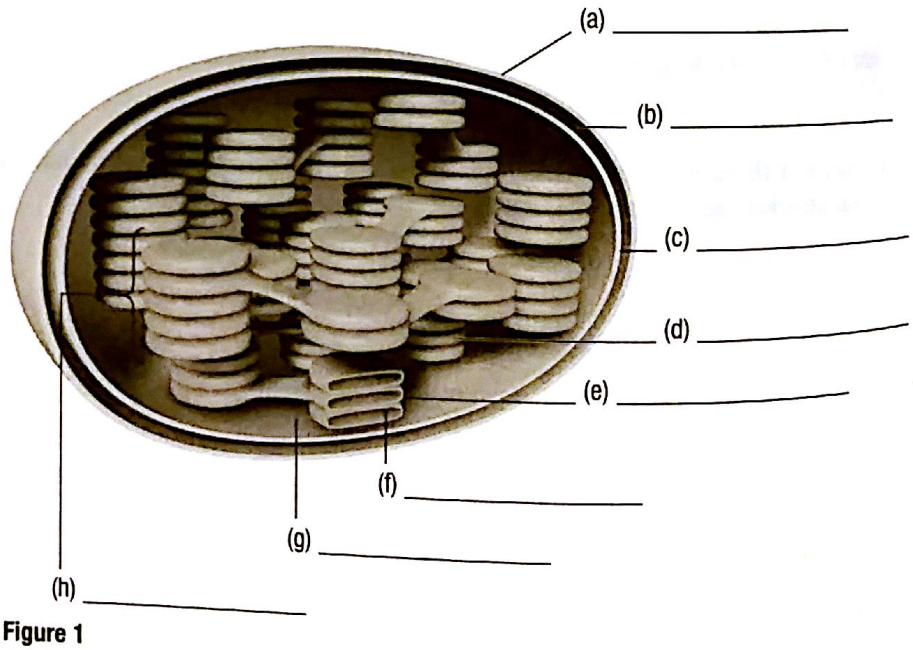


Figure 1

6. In what way does the thylakoid membrane affect the appearance of plants? K/U

MAIN IDEA: The Calvin cycle takes place in the stroma of the chloroplasts. It uses NADPH and ATP to convert carbon dioxide into simple carbohydrates.

7. Add labels to **Figure 2** to show the reactants and products of the Calvin cycle. K/U

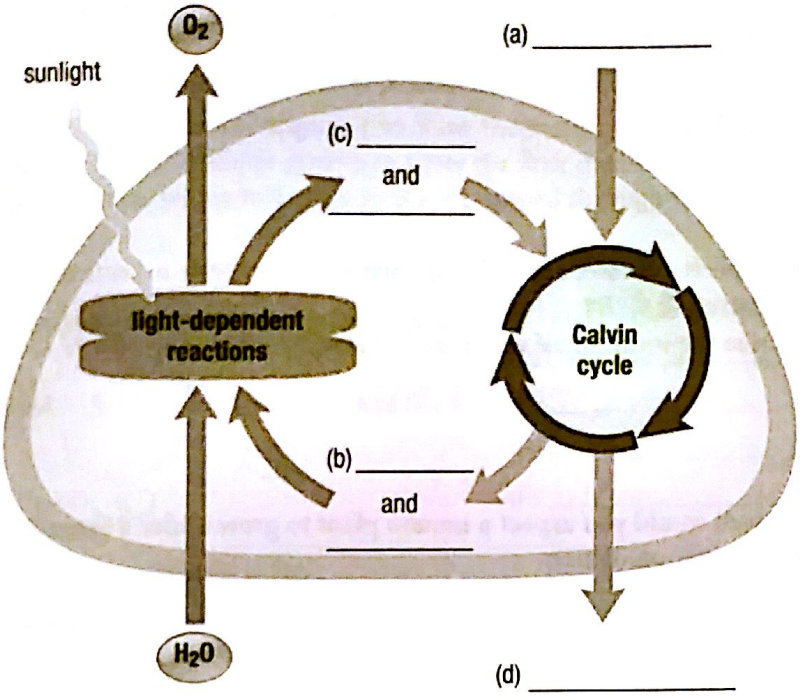


Figure 2

8. Explain the term "primary electron acceptor" in your own words. K/U C

MAIN IDEA: Chlorophylls, carotenoids, and other pigments absorb light energy during photosynthesis and are organized into two types of photosystems: photosystem I and photosystem II. Each photosystem contains a reaction centre surrounded by an antenna complex that helps capture photons. While both photosystems absorb light of slightly different frequencies, the action spectrum of both photosystems in green plants is highest in the red and blue regions of the spectrum.

9. Label **Figure 3**, which shows the pigment molecules in the antenna complex of a photosystem. K/U

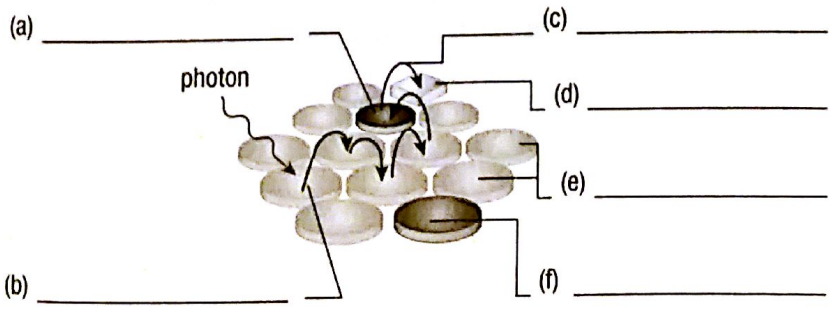


Figure 3

10. Explain differences between the structure and functions of two types of chlorophyll *a* molecules in the reaction centre. KU

11. State an example of an accessory pigment. Describe its purpose. KU

12. An action spectrum can be used by scientists to investigate aspects of photosynthesis. KU TI C

    (a) Describe the meaning of action spectrum in your own words.

    (b) How well would you expect a tomato plant to grow under a green light? Explain your prediction.

13. Draw a table to compare photosystem I and photosystem II. Use these headings: Photosystem I, Photosystem II, Type of chlorophyll, Wavelength(s) used, Products. KU C

Pathways of Photosynthesis

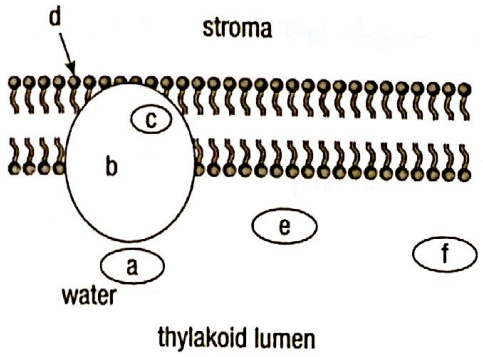
Vocabulary

rubisco

Textbook pp. 220–228

MAIN IDEA: The light-dependent reactions consist of photosystem I and photosystem II. The end product of photosystem II is the powerful oxidant $P680^+$. Electrons that are excited by the light energy in photosystem II pass through the electron transport system to photosystem I. The end result of the electron transport is the production of NADPH and ATP. In cyclic electron transport, extra ATP is produced but no NADPH.

1. Label the structures in **Figure 1** to show the main compounds and reactions in photosystem II. Include arrows to show the flow of electrons and the directions and locations where hydrogen ions are pumped through the membrane. K/U C



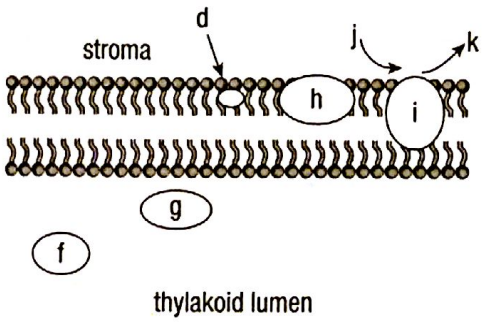
(a) _____
(b) _____
(c) _____
(d) _____
(e) _____
(f) _____

Figure 1

STUDY TIP

Diagrams
Clear, labelled diagrams can help you study for tests. When you review your diagram, take the time to trace each step of the process it describes, locating both products and reactants.

2. Label the structures in **Figure 2** to show the main compounds and reactions in photosystem I. Include arrows to show the flow of electrons and the directions and locations where hydrogen ions are pumped through the membrane. K/U C

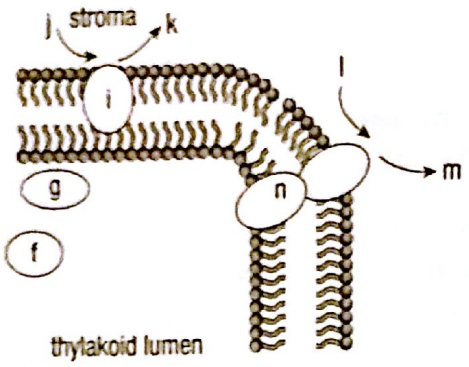


(d) _____
(f) _____
(g) _____
(h) _____
(i) _____
(j) _____
(k) _____

Figure 2

3. Describe the events that occur in the thylakoid lumen and explain the movement of protons within the thylakoid. K/U

4. Label the structures in **Figure 3** to show the main compounds and reactions in photosystem I and the synthesis of ATP. Include arrows to show the flow of electrons and the directions and locations where hydrogen ions are pumped through the membrane. K/U



(f) _____
(g) _____
(i) _____
(j) _____
(k) _____
(l) _____
(m) _____
(n) _____

Figure 3

5. Use **Table 1** to summarize the reactions of the light-dependent stage of photosynthesis. K/U

Table 1 Light-dependent Reactions

Stage	Summary
oxidation of P680	
oxidation–reduction of plastoquinone	
electron transfer of cytochrome complex and plastocyanin	
oxidation–reduction of P700	
electron transfer to $NADP^+$	
formation of NADPH	

6. During photosynthesis, the light energy is transferred to which molecules? K/U

7. Describe the function of the chlorophyll molecules, accessory pigments and proteins in a typical photosystem. K/U

8. What is the source of the electrons used in the photosynthesis reactions? K/U

9. (a) Linear electron transport results in an increased concentration of protons in what part of the chloroplast?

(b) What is this increased proton concentration used for? K/U

10. (a) Describe how ferredoxin functions with both photosystems functioning.

(b) Describe how ferredoxin functions with only photosystem I functioning. K/U

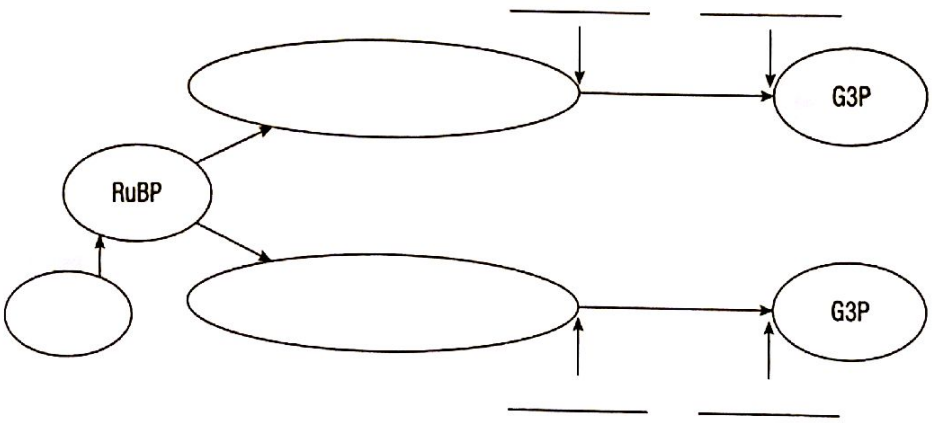
MAIN IDEA: The Calvin cycle consists of three phases: carbon fixation, reduction, and regeneration. For every three complete turns of the Calvin cycle, a single molecule of the 3-carbon molecule G3P is produced. G3P is the starting point for the synthesis of glucose, sucrose, starches, and many other organic molecules

11. Use **Table 2** to summarize the reactions that take place during each phase of the Calvin cycle. K/U

Table 2 The Calvin Cycle

Phase	Main points
carbon fixation	
reduction	
regeneration	

12. Add labels to the diagram below, which shows a single segment of the Calvin cycle that fixes only one carbon atom. Circle the areas that show carbon fixation and reduction K/U C



13. Glucose that is produced during photosynthesis has many uses in the plant. List four uses of glucose in the plant. K/U

Alternative Mechanisms of Carbon Fixation

Vocabulary

stomata
photorespiration
C_4 cycle
crassulacean acid metabolism (CAM)

Textbook pp. 231–234

MAIN IDEA: Many plants use the Calvin cycle (C_3 system) to fix carbon dioxide. However, some plants have evolved a C_4 pathway that all but eliminate the problem of of photo-respiration associated with C_3 plants.

1. Why do plants need to fix carbon from the atmosphere? K/U

STUDY TIP

Reviewing Carbohydrates
Review some complex carbohydrates in Chapter 1 to see how many carbon molecules they contain.

2. What is rubisco? K/U

3. Explain how the concentration of oxygen in the atmosphere affects the functioning of rubisco and can lead to photorespiration. K/U T/I

4. Add labels to **Figure 1** below, which shows the C_4 pathways. K/U C

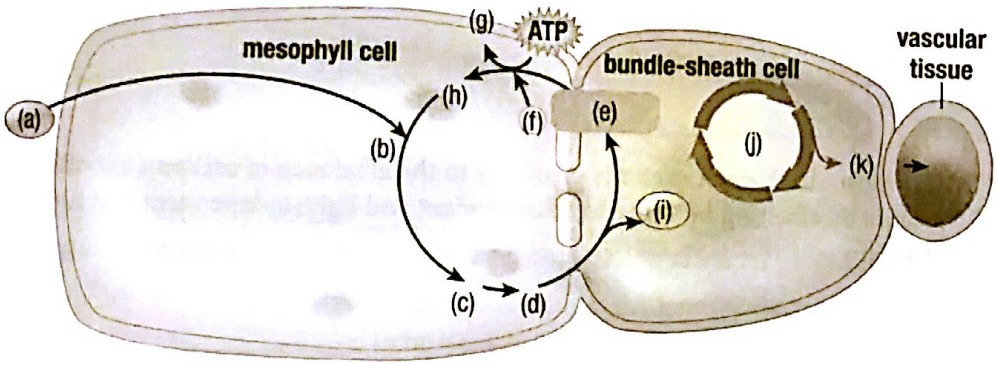


Figure 1

(a) _____ (e) _____ (i) _____
(b) _____ (f) _____ (j) _____
(c) _____ (g) _____ (k) _____
(d) _____ (h) _____

5. Using Figure 1 as a guide, make a sketch to show the differences between the arrangement of cells and the chemical pathways used in C_3 and C_4 plants. K/U C

MAIN IDEA: C_4 photosynthesis is a modification of C_3 photosynthesis, which is used to reduce photorespiration. C_4 plants are significantly more efficient than C_3 plants performing photosynthesis in hot and/or dry environment. Many cacti and succulent plants use crassulacean acid metabolism (CAM), which uses a C_4 cycle to fix carbon during the night and the Calvin cycle to fix carbohydrates during the day.

6. Draw a table to compare C_3, C_4, and CAM plants. Compare the following features:
   - number of cells needed
   - location of of major photosynthetic cells
   - the first molecule containing fixed carbon
   - relative efficiency
   - preferred habitat of this type of plant K/U T/I C

7. A warm, dry habitat presents problems to the efficiency of carbon fixation in plants by affecting both the light-dependent and light-independent reactions. Explain why this is so. K/U T/I

5.6 Photosynthesis and Cellular Respiration: A Comparison

Textbook pp. 237–240

MAIN IDEA: Aerobic cellular respiration and photosynthesis create a cycle. Some of the products of one process serve as the reactants for the other process, and vice versa. Plants and most other producers perform both photosynthesis and aerobic cellular respiration. Most consumers perform aerobic cellular respiration.

1. Explain how three common chemicals on Earth circulate through the processes of photosynthesis and aerobic cellular respiration. K/U

2. Long-living plants such as trees are sometimes called carbon sinks—places where carbon is stored without increasing the amount of carbon dioxide in the atmosphere. K/U T/I
   (a) What enables plants to act as carbon sinks?

   (b) How could forest fires release the carbon?

3. Could a plant exist that performs photosynthesis but does not perform cellular respiration? Explain your answer. T/I

MAIN IDEA: The chemical processes and physical structures that are associated with photosynthesis and aerobic cellular respiration share many similarities.

4. Describe two ways in which mitochondria and chloroplasts are similar. K/U

5. Use **Table 1** to compare photosynthesis and cellular respiration. K/U

Table 1 Photosynthesis versus Cellular Respiration.

	Photosynthesis	Cellular respiration
Water		
Oxygen		
Carbon dioxide		
NAD		
Electron flow		
Proton pumps		
Uses of ATP produced		
Glucose		
Site of cyclic process		
Site of electron flow		
Site of high proton concentration		
Chemical equation		

STUDY TIP

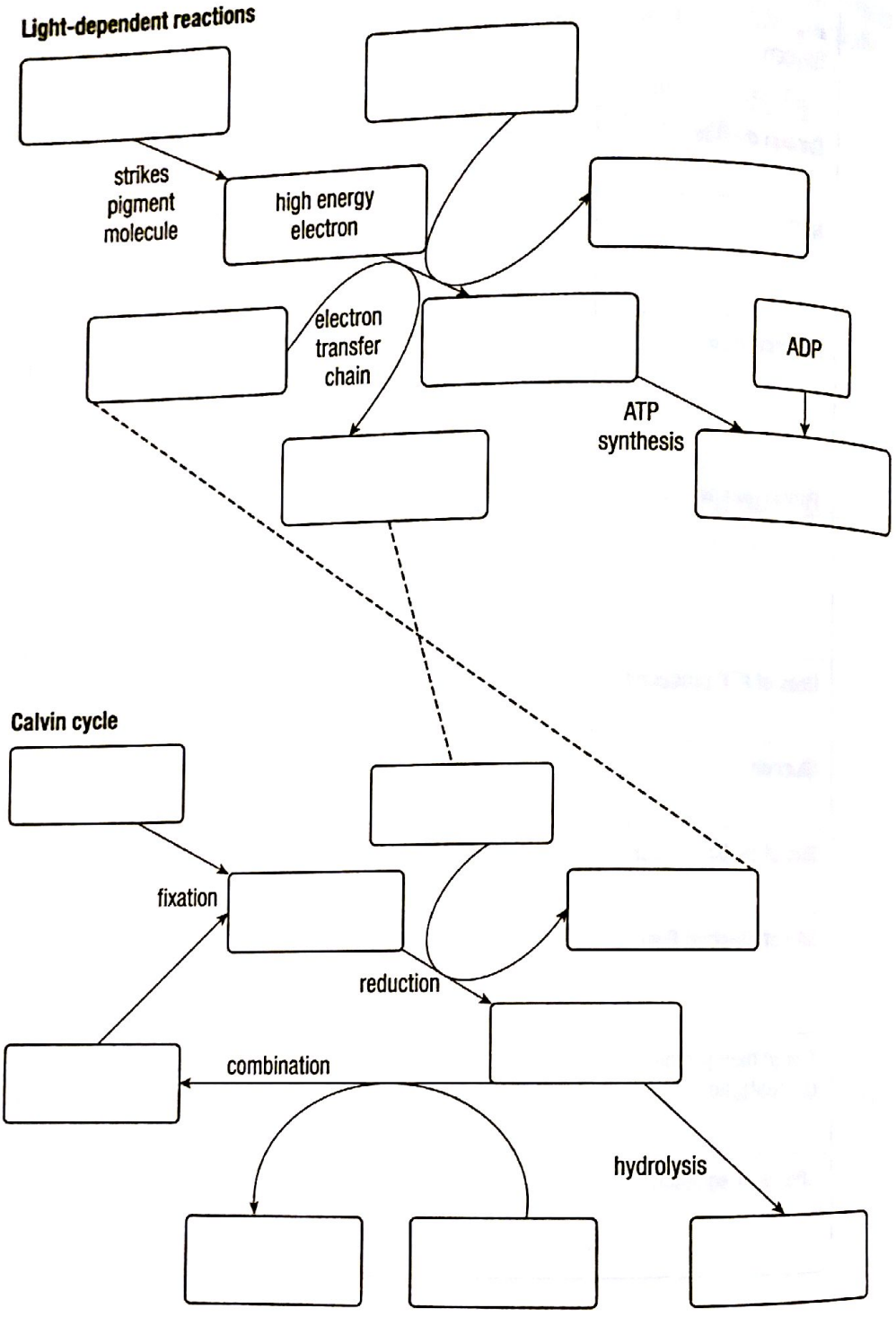
Venn Diagrams

Venn diagrams are useful tools for comparing processes that have some similarities and some differences. After you have completed this table, think about how you would present the information in a Venn diagram.

6. Photosynthesis and cellular respiration seem to be opposite processes. On a separate sheet of paper, list some everyday processes or events that seem to be opposites. Use a graphic organizer to help you. Provide diagrams to help you explain. T/I C A

Photosynthesis: The Energy of Life

The processes that make up photosynthesis are shown as flow charts below. Add the reactants and products to complete the summary of photosynthesis.



CHAPTER 5 QUESTIONS

K/U Knowledge/Understanding
T/I Thinking/Investigation
C Communication
A Application

1. When photosynthetic organisms use water labelled with ^{18}O isotopes, ^{18}O is found in the oxygen produced by photosynthesis but not in the carbohydrate products. This can lead to which of the following conclusions? (5.3) K/U
   (a) The oxygen in the carbohydrate must come from carbon dioxide.
   (b) Both water and carbon dioxide are sources of gaseous oxygen.
   (c) Carbon dioxide is a possible source of oxygen gas.
   (d) ^{18}O isotopes behave differently than ^{16}O isotopes do.
2. What happens to the electrons that are released as a result of light absorption by chlorophyll? (5.2) K/U
   (a) They combine with H^+ ions and oxygen to form water.
   (b) They are used directly in the fixation of carbon during the Calvin cycle.
   (c) They reduce photosystem I chlorophyll molecules.
   (d) They reduce photosystem II chlorophyll molecules.
3. Indicate whether each statement is true or false. If you think a statement is false, rewrite it to make it true. (5.1, 5.2, 5.6) K/U
   (a) During photosynthesis light energy is transferred to ADP and $NADP^+$, forming ATP and NADPH.

   (b) Light energy is principally transferred to the primary elecron receptor by chlorophyll *b*.

   (c) In comparing respiration and photosynthesis, respiration is exergonic while photosynthesis is endergonic.

   (d) The source of electrons in photosynthesis is chlorophyll.

4. Circle the steps that are part of the Calvin cycle. (5.2) K/U
   A. ATP molecules are needed to keep the reactions going.
   B. The process makes $NADPH + H^+$.
   C. Reduction occurs.
   D. Oxygen is a product.
   E. Photophosphorylation occurs.
   F. Carbon fixation occurs.
   G. Takes place in the thylakoids of chloroplasts.
5. A type of herbicide works by disrupting the structure of the internal membranes of a chloroplast. Which process of photosynthesis is the most affected? (5.2) K/U T/I A

6. Photophosphorylation specifically refers to the synthesis of _____ using _____. (5.2) KU

7. Which of the following statement(s) concerning light absorption by chlorophyll is correct? Circle your answer(s). (5.2) KU
   A. It can take place during the fixation of carbon.
   B. It involves NADP.
   C. It occurs in the thylakoid of the chloroplast.
   D. Oxygen gas is produced.
   E. It Involves at least one carbon-containing compound.

8. Ribulose bisphosphate is converted to 3-phosphoglycerate (PGA) with the addition of _____ and _____. (5.2) KU

9. What is the primary cause of photorespiration? (5.4) KU

10. How does the law of the conservation of energy and the first law of thermodynamics apply to the light-dependent reactions of photosynthesis? (5.2) KU C A

11. You are touring a local greenhouse and you notice that many plants in one room are smaller than identical plants in the other rooms. You speak with the manager who says she has been having a problem recently with growing plants in this particular room. Later in the conversation you learn that the manager has looked at factors such as light levels, temperature and soil nutrients, yet all these are the same in both rooms. What factors would you suggest testing for? How would each of these factors affect the growth of plants? (5.1, 5.4) KU TI A