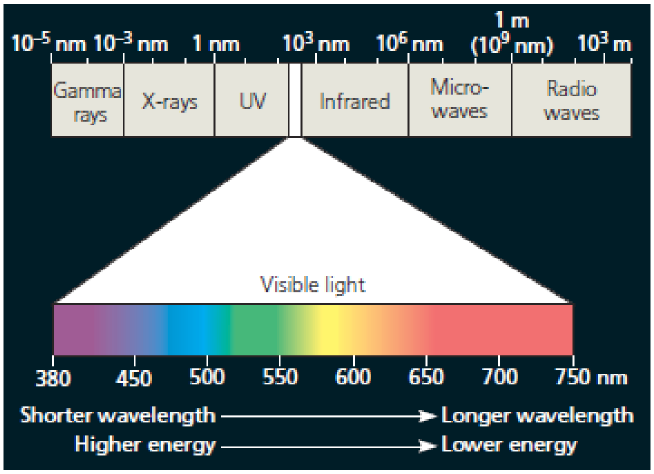
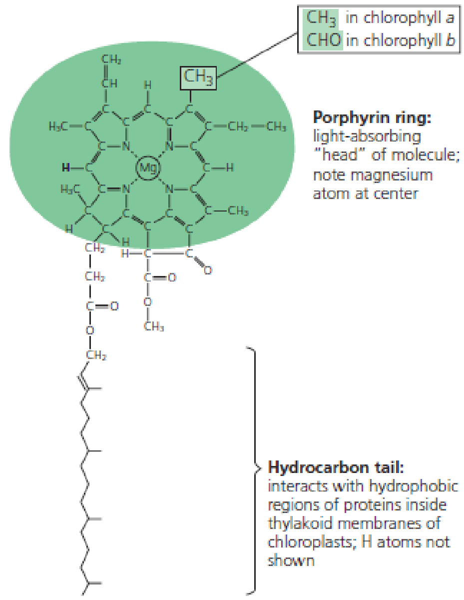
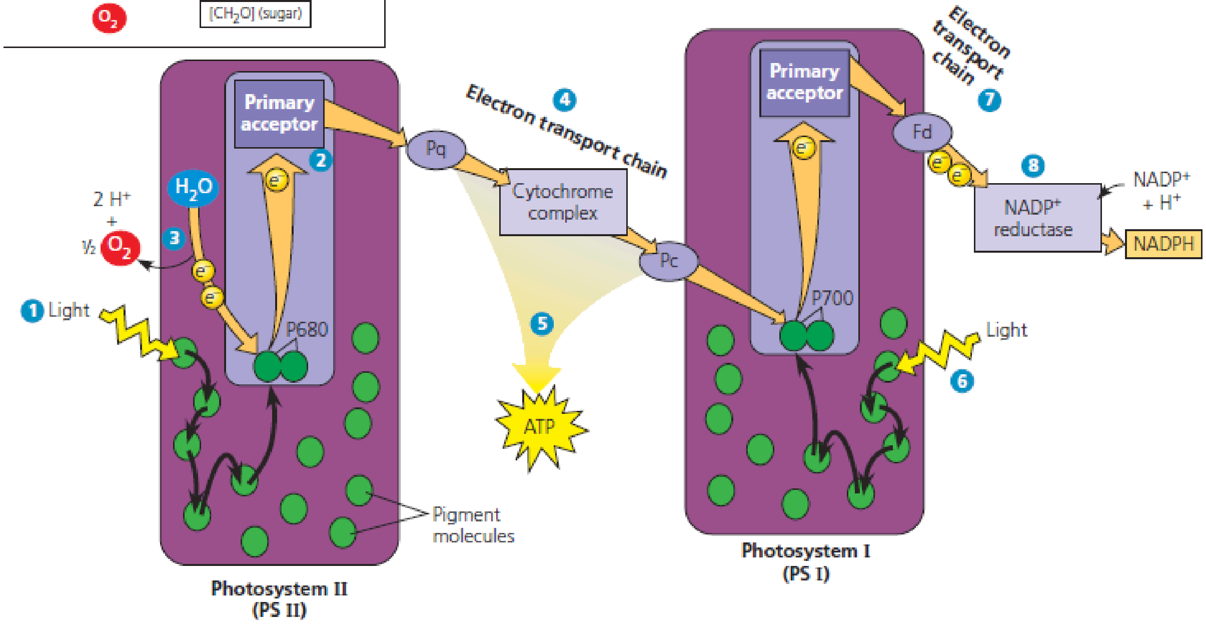
Cheat Sheet

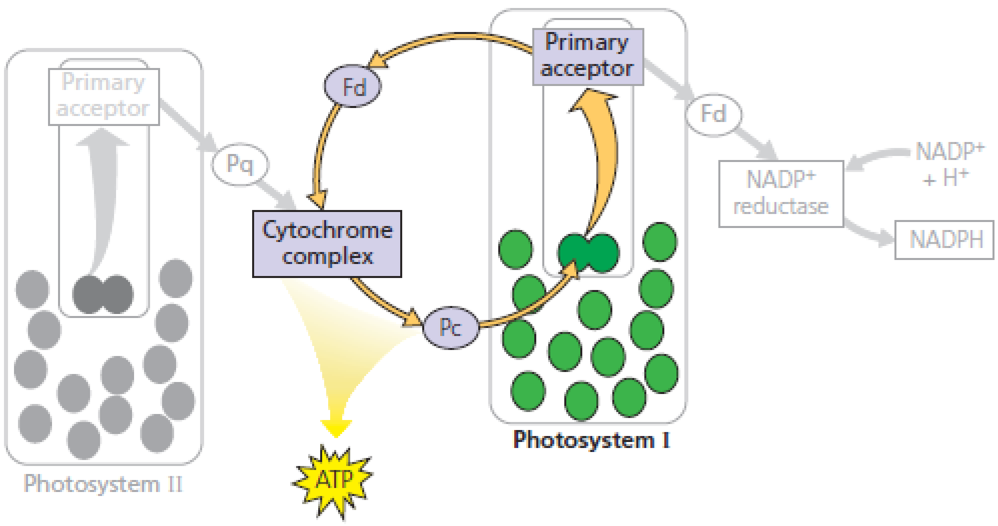


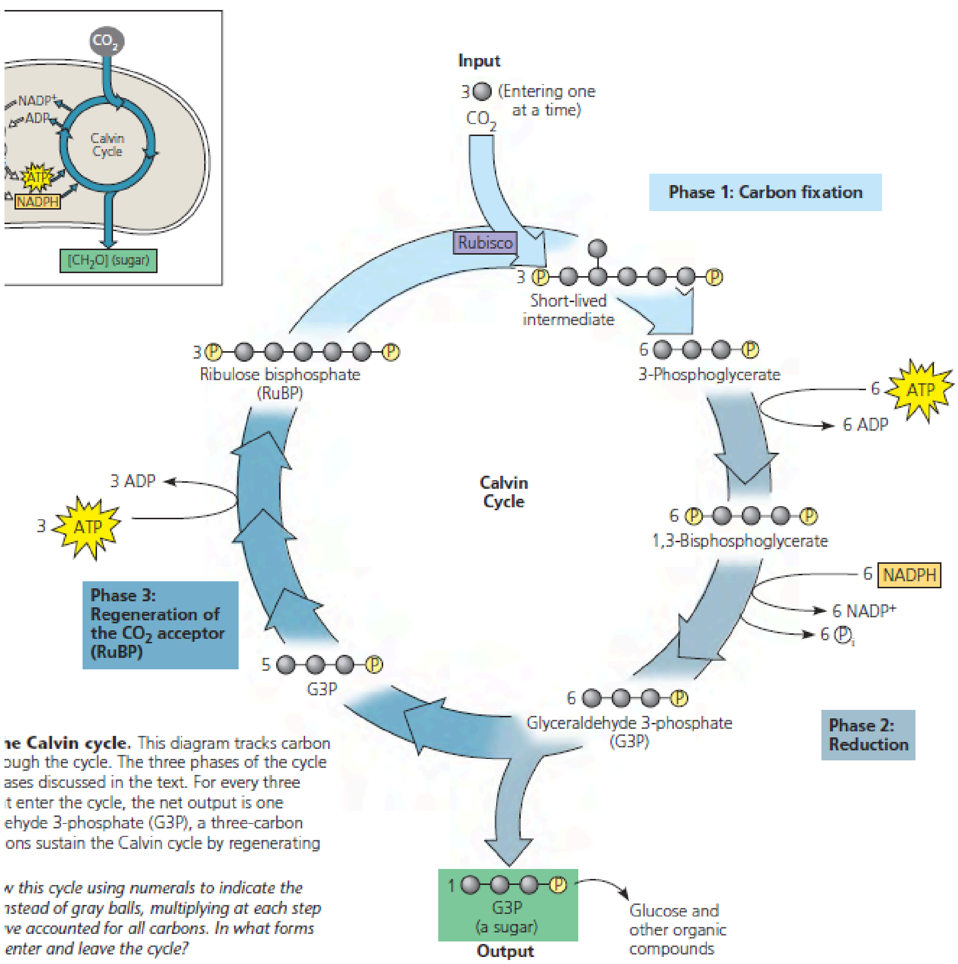
▲ **Figure 10.7 The electromagnetic spectrum.** White light is a mixture of all wavelengths of visible light. A prism can sort white light into its component colors by bending light of different wavelengths at different angles. (Droplets of water in the atmosphere can act as prisms, forming a rainbow; see Figure 10.1.) Visible light drives photosynthesis.



▲ **Figure 10.11 Structure of chlorophyll molecules in chloroplasts of plants.** Chlorophyll *a* and chlorophyll *b* differ only in one of the functional groups bonded to the porphyrin ring. (Also see the space-filling model of chlorophyll in Figure 1.4, p. 5.)







ne Calvin cycle. This diagram tracks carbon
ough the cycle. The three phases of the cycle
ases discussed in the text. For every three
t enter the cycle, the net output is one
ehyde 3-phosphate (G3P), a three-carbon
ons sustain the Calvin cycle by regenerating

w this cycle using numerals to indicate the
nstead of gray balls, multiplying at each step
ve accounted for all carbons. In what forms
enter and leave the cycle?

Chapter 10 Questions

1. **What type of autotroph are most plants?**
2. How many chloroplasts are in a chunk of leaf with a top surface of 1 mm^2?
3. **Where are chloroplasts mainly found?**
4. **Through what does CO_2 enter and oxygen exit the leaf?**
5. **What are the function of veins in plants?**
6. **How many chloroplasts does a typical mesophyll cell have? How big are they?**
7. **What is the dense fluid that the membranes of the chloroplast surround called?**
8. **What are thylakoids?**
9. **What are stacks of thylakoids called?**
10. **What is chlorophyll and where does it reside?**
11. **What is the direct products of photosynthesis?**
12. **How much water is consumed by the plant and how much is produced?**
13. **Where is the oxygen released from plants derived from?**
14. **What is the photosynthetic equation in sulfur bacteria? How about in general?**
15. **Draw where the reactants in photosynthesis go in the products.**
16. **What are the two stages of photosynthesis?**
17. **What occurs in the first stage?**
18. **What is carbon fixation?**
19. **What occurs in the second stage of photosynthesis?**
20. **When does the second stage usually happen?**
21. **Where does each of the stages occur?**
22. **How does electromagnetic energy travel?**
23. **Draw the electromagnetic spectrum and important wavelengths.**
24. **What discrete particles make up light?**
25. **What are pigments?**
26. **What measures the ability of a pigment to absorb various wavelengths of light and how?**
27. **What is an absorption spectrum?**
28. **What are three types of pigments in chloroplasts?**
29. **What does an action spectrum do and how is it prepared for photosynthesis?**
30. **Draw chlorophyll. What is the difference between chlorophyll a and b?What the two parts of a chlorophyll molecule?**
31. **What are carotenoids and what are their functions?**
32. **What are photoprotective chloroplast carotenoids similar to?**
33. **What are carotenoids and similar molecules advertised as in health products?**
34. **What occurs when an atom absorbs a photon?**
35. **What are photosystems?**
36. **What is a reaction-center complex?**
37. **What makes up a light-harvesting complex?**
38. **What happens once a pigment absorbs a photon in a light-harvesting complex?**

39. What are the two types of photosystems?
40. What are the differences between the two types?
41. What is linear electron flow?
42. Draw steps of linear electron flow in the light reactions.
43. What is cyclic electron flow? Draw out the steps.
44. How do several photosynthetic bacteria carry out photosynthesis?
45. What is the three-carbon sugar produced from the Calvin cycle?
46. How many cycles are required to create the three-carbon sugar?
47. What are the three phases of the Calvin cycle?
48. How does the calvin cycle incorporate each CO_2 molecule?
49. What occurs in the second stage of the Calvin cycle?
50. What occurs in the third stage of the Calvin cycle?
51. What do plants do on hot, dry days?
52. What are C3 plants? Give examples?
53. What is photorespiration and why does it exist?
54. What are the two most important photosynthetic adaptations for reducing photorespiration?
55. What is special about C_4 plants?
56. What are examples of CAM plants?
57. What do CAM plants do?
58. In most plants, in what form is carbohydrate transported out of leaves?
59. How many metric tons of carbohydrate per year is photosynthesis estimated to make?

Chapter 10 Answers

1. Most are photoautotrophs
2. half a million
3. Mesophyll, tissue in interior of leaf
4. Microscopic pores called stomata
5. Deliver water to leaves and export sugar to nonphotosynthetic parts of plant from leaves
6. 30-40, 2-4 μm by 4-7 μm
7. stroma
8. Third, innermost membrane system, sacs that segregate stroma from thylakoid space inside the sacs
9. granum
10. Green pigment that resides in thylakoid membranes of chloroplast
11. Oxygen and a 3-carbon sugar that can be made into glucose
12. 12 molecules consumed, 6 produced
13. H_2O
14. $CO_2 + 2H_2S \rightarrow [CH_2O] + H_2O + 2S$, $CO_2 + 2H_2X \rightarrow [CH_2O] + H_2O + 2X$
15. C in CO_2 to C in glucose, O_2 in CO_2 goes to glucose and H_2O, H in water goes to H in glucose and water, O goes to O in O_2
16. Light reactions and Calvin cycle
17. light reactions convert solar energy to chemical energy by splitting water to give off O_2 and provide a source of electrons, electrons transferred to $NADP^+$ (nicotinamide adenine dinucleotide phosphate), differs only in extra phosphate group, light react
18. Incorporation of carbon into organic compounds
19. CO_2 incorporated into organic molecules, fixed carbon reduced to carbohydrate by addition of electrons (NADPH provides reducing power, ATP, both produced in light reactions), also called dark reactions, or light-independent reactions
20. usually occurs during daylight
21. Light reactions in thylakoids, Calvin cycle in stroma
22. Travels in rhythmic waves, disturbances of electric and magnetic fields
23. DRAW IT
24. Photons that act like objects (have fixed quantity of energy, inversely related to wavelength of light)
25. Substances that absorb visible light
26. Spectrophotometer, directs beams of light with different wavelengths through solution of pigment and measures fraction of light transmitted at each wavelength
27. Graph plotting a pigment's light absorption versus wavelength
28. Chlorophyll a (key light-capturing pigment that participates directly in LRs), chlorophyll b (accessory pigment) and carotenoids (accessory pigments)
29. Profiles relative effectiveness of different wavelengths of radiation in driving the process (for photosynthesis, prepared by illuminating chloroplasts with light of different colors and then plotting wavelength against some measure of photosynthetic rate)

30. DRAW IT. Chlorophyll a(CH_3) is more blue green, chlorophyll b(CHO) is more olive green Porphyrin ring (light-absorbing head of molecule with magnesium ion at the center) and hydrocarbon tail (interacts with hydrophobic protein parts in thylakoid membrane)
31. Accessory pigments that are hydrocarbons that are various shades of yellow and orange (may broaden spectrum of colors that can drive photosynthesis), may provide photoprotection (absorb/dissipate excessive light energy that would otherwise damage chlorophyll or interact with oxygen to form dangerous reactive oxidative molecules)
32. Protective carotenoids in the human eye
33. “phytochemicals”, have antioxidant properties
34. An electron is elevated to higher orbital (normal orbital = ground state, high orbital = excited states), only photons with energy exactly equal to energy diff between ground and excited state are absorbed (energy diff varies from molecule to molecule, causes unique absorption spectrums), excited state is unstable so excited electrons drop back to ground state in billionth of second, release excess energy as heat, some pigments give off light when electrons fall and photons are given off causing fluorescence
35. Composed of reaction-center complex surrounded by several light-harvesting complex (proteins, chlorophyll, and other small organic molecules)
36. Organized association of proteins holding a special pair of chlorophyll a molecules and a primary electron acceptor
37. Various pigments bound to proteins
38. Energy is passed from pigment molecule to pigment molecule until passed to pair of chlorophyll a molecules in reaction-center complex, which transfers electron to primary electron acceptor (which becomes reduced in a redox reaction)
39. Photosystem II (PS II) and photosystem I (PS I), named in order of discovery, PS II acts first in light reactions
40. Each has specific primary electron acceptor, chlorophyll a molecule, and proteins. Reaction-center chlorophyll a in photosystem II called P680 since best at absorbing 680 nm wavelength light, P700 in photosystem I (P680 and 700 nearly identical, but different proteins affects electron distribution)
41. Flow of electrons through photosystems and other molecular components of thylakoid, occurs during light reactions
42. Step 1: Photon of light strikes one of pigment molecules in PS II, energy relayed to P680 pair

    Step 2: Excited electron transferred to primary electron acceptor (results in $P680^+$)

    Step 3: Enzyme splits water molecule into 2 e^-, 2 H^+ and oxygen atom, Electrons supplied one by one to $P680^+$ pair, electrons replace electron transferred to primary electron acceptor ($P680^+$ is strongest biological oxidizing agent known), H^+ released into thylakoid space, oxygen atom combines with oxygen atom generated by another water molecule to form O_2

    Step 4: Photoexcited electron passes from primary electron acceptor of PS II to PS I via electron chain made up of electron carrier plastoquinone (Pq), a cytochrome complex, and protein called plastocyanin (Pc), each component carries out redox reactions, releasing free energy used to pump protons into thylakoid space

Step 5: Proton motive force used to make ATP through chemiosmosis
Step 6: Light energy excites electron of P700 pair of chlorophyll a molecules, transferred to primary electron acceptor, leaving electron hole ($P700^+$ acts as acceptor of electrons in electron transport chain
Step 7: Photoexcited electrons passed in redox reactions down a second electron transport chain through protein ferredoxin (Fd), this chain does not make proton gradient or ATP
Step 8: Enzyme $NADP^+$ reductase transfers electrons from Fd to $NADP^+$, two electrons required to reduce to NADPH, more available for reactions of Calvin cycle

43. DRAW IT, no release of oxygen or production of NADPH, generates ATP
44. Single photosystem (similar to either PS II or PS I), exclusively cyclic electron flow, examples are purple and green sulfur bacteria (some prokaryotes, such as cyanobacteria, and some eukaryotes, have both PSs and can use cyclic electron flow)
45. Glyceraldehyde 3-phosphate (G3P)
46. 3, one per carbon
47. Carbon fixation, reduction, and regeneration of CO_2 acceptor
48. Attached one at a time to 5-carbon sugar called ribulose biphosphate (RuBP), catalyzed by RuBP carboxylase-oxygenase (rubisco, most abundant protein in chloroplasts and probably on Earth), produces short-lived six-carbon intermediate that immediately splits into 2 molecules of 3-phosphoglycerate per CO_2 fixed since so energetically unstable
49. Each 3-phosphoglycerate molecule receives an additional phosphate group from ATp, becoming 1,3-biphosphoglycerate. Pair of electrons from NADPH reduces carboxyl group on 1,3-biphosphoglycerate to aldehyde group of G3P, stores more potential energy, 6 G3P produced, only net gain of 1 (5 G3P used to regenerate 3 RuBP)
50. Carbon skeletons of 5 G3P rearranged into 3 RuBP, requiring 3 molecules of ATP
51. Close stomata, conserving water but reducing CO_2 levels
52. Plants that use rubisco to fix carbon, since first organic product of fixation is 3-phosphoglycerate. Examples = Rice, wheat, soybeans
53. In C_3 plants, when CO_2 gets scarce and O_2 builds up, rubisco adds O_2 to Calvin cycle and product splits to for two-carbon compound that is rearranged and split by peroxisomes and mitochondria, releasing CO_2, requires ATP, produces no sugar. It is evolutionary baggage from when there was little O_2 and photorespiration would not affect the plant much, some evidence says that it may provide protection against damaging product of light reactions which build up when Calvin cycle slows due to low CO_2
54. C_4 photosynthesis and crassulacean acid metabolism (CAM)
55. Preface Calvin cycle with alternate mode of carbon fixation that forms 4-carbon compound as first product (believed to have evolved independently at least 45 times and is used at least 19 plant families), include sugarcane and corn (grass family). Have bundle-sheath cells (arranged into tightly packed sheaths around veins of leaf) and mesophyll cells (closely associated and never more than 2-3 cells from bundle sheath cells). Calvin cycle confined to bundle-sheath cells, mesophyll cells incorporate CO_2
Step 1: PEP carboxylase (enzyme only in mesophyll cells) adds CO_2 to phosphoenolpyruvate (PEP) to form 4-carbon oxaloacetate. PEP has higher affinity for

CO_2 than rubisco, not affinity for O_2
Step 2: 4-carbon products (such as malate) moves to bundle-sheath cells through plasmodesmata
Step 3: 4-carbon compounds release CO_2, which is fixed into organic materials by rubisco and Calvin cycle, same reaction regenerates pyruvate, which is transferred to mesophyll cells, where ATP converts pyruvate to PEP. Bundle sheath cells carry out cyclic electron flow to generate extra ATP (contain only PS I)

56. Succulent plants, cacti, pineapples
57. Open stomata during night and close them during day, helping conserve water, prevents CO_2 from entering leaves. During night, plants take up CO_2 and incorporate it into organic acids (called crassulacean acid metabolism after Crassulaceae family of succulents where first discovered). Mesophyll cells store organic acids in vacuoles until morning, when stomata close. During day, light reactions and Calvin cycle occur.
58. Sucrose
59. 150 billion metric tons