Chloroplasts (page 23)

1. (a) Stroma
   (b) Stroma lamellae
   (c) Outer membrane
   (d) Granum
   (e) Thylakoid
   (f) Inner membrane

2. (a) Chlorophyll is found in the thylakoid membrane.
   (b) Chlorophyll is a membrane-bound pigment found in and around the photosystems that embedded in the membranes. Light capture by chlorophyll is linked to electron transport in the light dependent reactions.

3. The internal membranes provide a large surface area for binding chlorophyll molecules and capturing light. Membranes are stacked in such a way that they do not shade each other.

4. Chlorophyll absorbs blue and red light but reflects green light, so leaves look green to the human eye.

Photosynthesis (page 24)

1. Importance of photosynthesis (in any order):
   (a) Transforms light energy into chemical energy available to food chains.
   (b) Creates organic molecules used as building blocks for creating more complex molecules.
   (c) Releases free oxygen into the atmosphere; oxygen is required by meny other life forms.

2. (a) **NADP**: Carries H_2 from the light dependent phase to the light independent reactions.
   (b) **ATP**: Provides energy for constructing glucose molecules using hydrogens (delivered by NADP) and carbon dioxide.
   (c) **Chlorophyll**: Absorbs the light energy for photosynthesis, producing high energy electrons. These are used to make ATP and NADPH. The photosystems (of which chlorophylls are a part) also split water molecules, to release H^+ (for use in the light independent reactions) and liberate free O_2.
   (d) **Light**: Provides the ultimate energy source to drive the light dependent reactions (creation of ATP and reduced NADP).

Chloroplasts (page 23)

1. The absorption spectrum of a pigment is that wavelength of the light spectrum absorbed by a pigment, e.g. chlorophyll absorbs red and blue light and appears green. Represented graphically, the absorption spectrum shows the relative amounts of light absorbed at different wavelengths.

2. Accessory pigments absorb light wavelengths that chlorophyll *a* cannot absorb, and they pess their energy on to chlorophyll *a*. This broadens the action spectrum over which chlorophyll *a* can fuel photosynthesis.

Light Dependent Reactions (page 26)

1. **NADP**: Carries H_2 from the light dependent phase to the light independent reactions.

2. **Chlorophyll**: These pigment molecules trap light energy and produce high energy electrons. These are used to make ATP and NADPH. The chlorophyll molecules also split water, releasing H^+ for use in the light independent reactions and liberating free O_2.

3. Light dependent (D) phase takes place in the grana (thylakoid membranes) of the chloroplast and requires light energy to proceed. The light dependent phase generates ATP and reducing power in the form of NADPH. The electrons and hydrogen ions come from the splitting of water.

4. The ATP synthesis is coupled to electron transport. When the light strikes the chlorophyll molecules, high energy electrons are released by the chlorophyll molecules. The energy lost when the electrons are passed through a series of electron carriers is used to bond a phosphate to ADP to make ATP.
   Note: ATP is generated (in photosynthesis and cellular respiration) by **chemiosmosis**. As the electron carriers pick up the electrons, protons (H^+) pass into the space inside the thylakoid, creating a high concentration of protons there. The protons return across the thylakoid membrane down a concentration gradient via the enzyme complex, ATP synthetase that synthesizes the ATP (also called ATP synthase or ATPase).

5. (a) **Non-cyclic (photo)phosphorylation**: Generation of ATP using light energy during photosynthesis. The electrons lost during this process are replaced by the splitting of water.
   (b) The term non-cyclic **photo**phosphorylation is also (commonly) used because it indicates that the energy for the phosphorylation is coming from light.

6. (a) In **cyclic photophosphorylation**, the electrons lost from photosystem II are replaced by those from photosystem I rather than from the splitting

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of water. ATP is generated in this process, but not NADPH. **Note**: In the cell, both cyclic and non-cyclic photophosphorylation operate to different degrees to balance production of NADPH and ATP.
   (b) The non-cyclic path produces ATP and NADH in roughly equal quantities but the Calvin cycle uses more ATP than NADPH. The cyclic pathway of electron flow makes up the difference.

7. It shows that a complex reaction pathway is made of less complex pathways that can operate independently. These simple pathways can then be linked through common intermediates, generating complex pathways.

Light Independent Reactions (page 28)

1. (a) 6 (b) 6 (c) 12
   (d) 12 (e) 12 (f) 6
   (g) 2 (h) 1

2. RuBisCo catalyses the reaction that splits CO_2 and joins it with ribulose 1,5-bisphosphate. It fixes cerbon from the atmosphere.

3. Triose phosphate (note that you may also see this referred to as glyceraldehyde-3-phosphate, GALP, G3P or PGAL)

4. $6CO_2 + 18ATP + 12\ NADPH + 12H^+$
   $\rightarrow 1\ glucose + 18ADP + 18P_i + 12\ NADP^+ + 6H_2O$

5. The Calvin cycle will cease in the dark in most plants because the light dependent reactions stop, therefore no NADPH or ATP is produced. At night, stomata also close, reducing levels of CO_2 (there will still be some CO_2 in the leaf as a waste product of respiration).

energy and are therefore **exergonic**. In contrast, **anabolism** involves metabolic reactions that build larger molecules from smaller ones. Anabolic reactions include protein synthesis and photosynthesis. They require the input of energy and are **endergonic**.