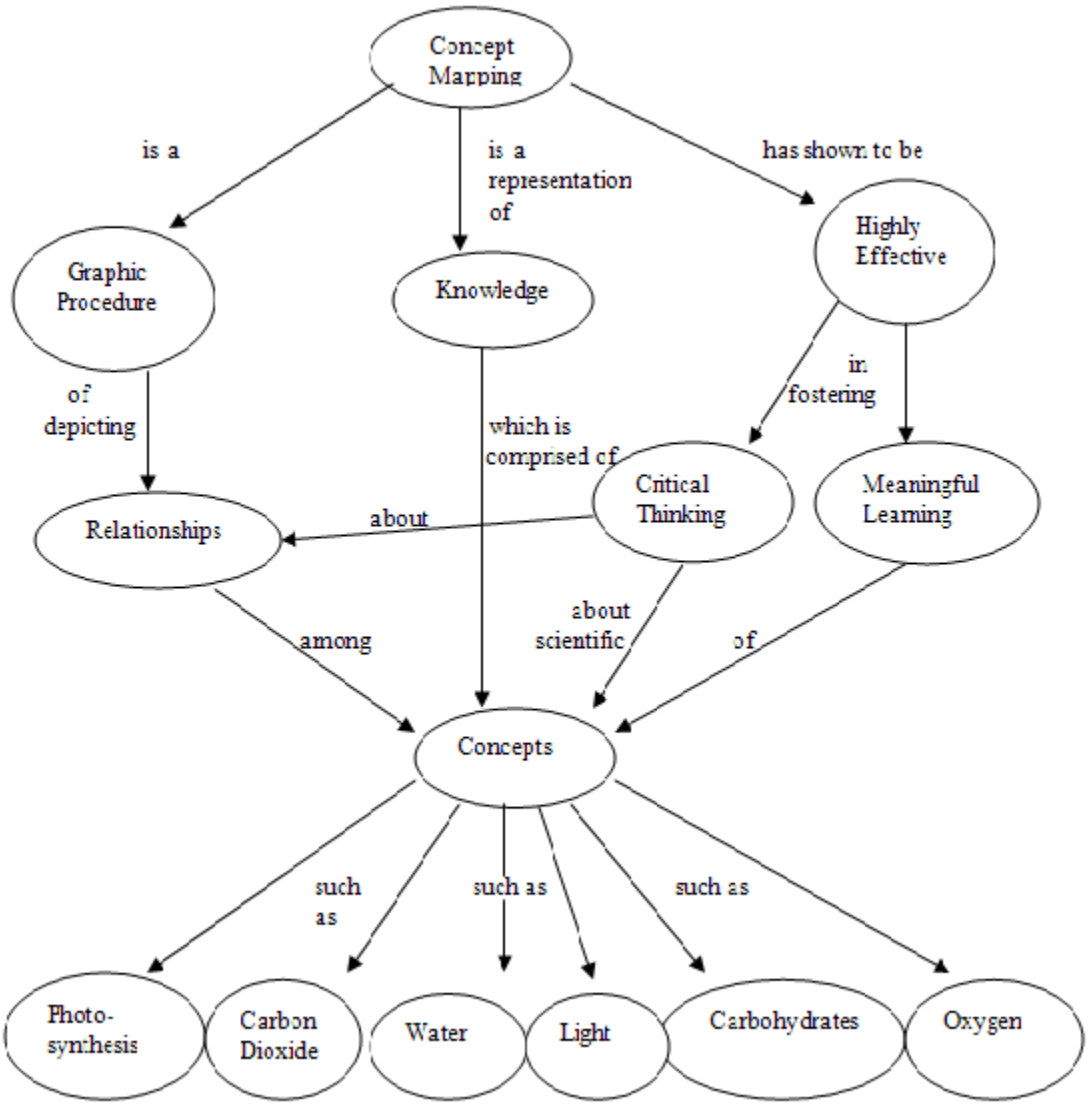
Scenario: Mapping Photosynthesis

Photosynthesis is arguably the most important biological process on the Earth. All of the energy for the planet can be traced to the sun, but only **photosynthetic** organisms (plants, algae and some cyanobacteria) can directly utilize this energy. Through highly coordinated metabolic pathways, these photoautotrophic organisms capture solar energy and transform solar energy into the chemical bond energy of carbohydrates and other organic materials, providing usable energy for ecosystems across the planet. As these organisms conduct photosynthesis they also liberate oxygen and consume carbon dioxide, shaping the conditions of the Earth's atmosphere.

Because of the central position of photosynthesis to all life, it is vital that all individuals—not just biologists—have an accurate understanding of the process. Thus, it is especially important that biology teachers have an accurate and comprehensive understanding of the events of photosynthesis. In addition to their conventional coursework, many biology departments require special courses for students who are interested in teaching biology. These courses are designed to ensure that they are well-prepared to effectively teach the fundamental concepts in the discipline, like photosynthesis.

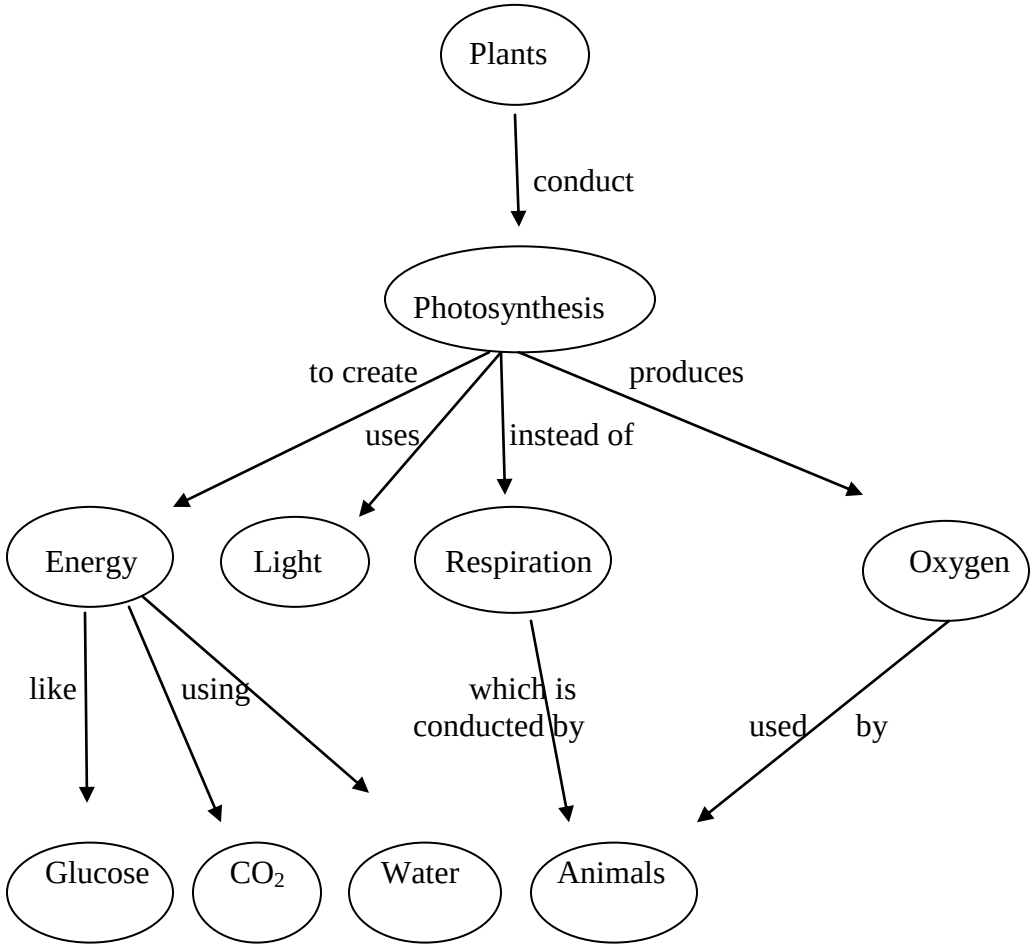
One tool that may be used to monitor and assess prospective biology teachers' understanding of key concepts during their course of study is that of **concept mapping**. Concept mapping is a technique to graphically organize knowledge into a hierarchy of concepts. Within a map, concepts are linked to related concepts by lines, which are labeled with linking words to define their relationships, forming a proposition. Maps are generally hierarchical, with broader concepts at the top, and more specific concepts below. Rich concept maps have cross-links connecting concepts in one branch of the map to concepts in another. Concept maps reveal an individual's knowledge structure and vary by individual. They are useful in identifying misconceptions and gaps in one's knowledge structure about a particular concept. A concept map of 'concept mapping' illustrates the technique (Figure 1).

Figure 1. Concept map of 'Concept Mapping'



Consider the concept map of 'Photosynthesis' produced by a student entering the program for biology teachers (Figure 2).

Figure 2. Student's Pre-Instruction Student Concept Map



In the next class meeting you will work in small collaborative groups to analyze and evaluate student responses to test questions about photosynthesis.

Each person in the group will act as the 'facilitator' for one question set, leading the group discussion, promoting input from each of the other students (who will be acting as 'discussants') and formalizing the group response. In the role of a discussant, students provide their knowledge, experience and perspectives, compare and contrast the inputs of other members of the group and collaborate in the formulation of the group response. At the end of the activity, you may be called on to present your group's answers to one of the question sets (not necessarily the one you were the facilitator for). You will act as both a facilitator and a discussant in the activity.

Pre-Activity Assignment: **Mapping Photosynthesis**

Name _____

Carefully read 'Mapping Photosynthesis' and answer the following questions.

1. In the concept map of photosynthesis, the student links three propositions to form the strand: 'Plants conduct photosynthesis instead of respiration which is conducted by animals.' This statement _____.
    a. would be accurate if it indicated that plants conduct photorespiration instead of respiration
    b. is scientifically accurate
    c. would be accurate and more comprehensive if it accounted for algae & cyanobacteria which are also photosynthetic
    d. is a misconception, as plants conduct both photosynthesis and respiration
    e. would be accurate and more comprehensive if it accounted for fungi and bacteria that also are not photosynthetic

2. In the concept map of photosynthesis, the student forms and connects the propositions: 'Plants conduct photosynthesis to create energy.' This statement _____.
    a. is scientifically accurate
    b. is a misconception, as energy is transformed, not created, during photosynthesis
    c. is accurate for CAM plants, but not C_4 plants
    d. is accurate for C_3 plants, but not CAM plants
    e. would be accurate and more comprehensive if it accounted for algae & cyanobacteria

3. Other students indicated in their concept maps that 'Photosynthesis occurs in two sets of reactions referred to as the Light-dependent Reactions and the Calvin cycle.' If this student were to indicate the products of the light-dependent reactions in her map, the map should include all of the following terms except _____.
    a. glucose
    b. ATP
    c. NADPH
    d. O_2

4. To indicate an accurate understanding of where the oxygen produced during photosynthesis comes from, she should connect the term 'oxygen' to the concept of _____.
    a. water
    b. carbon dioxide
    c. glucose
    d. NADPH
    e. chlorophyll

5. In the next class meeting you will work in small collaborative groups to analyze and evaluate student responses to test questions about photosynthesis.

   Each person in the group will act as the 'facilitator' for one question set, leading the group discussion, promoting input from each of the other students (who will be acting as 'discussants') and formalizing the group response. In the role of a discussant, students provide their knowledge, experience and perspectives, compare and contrast the inputs of other members of the group and collaborate in the formulation of the group response. At the end of the activity, you may be called on to present your group's answers to one of the question sets (not necessarily the one you were the facilitator for). You will act as both a facilitator and a discussant in the activity.

   Download and critically analyze the reading "Mapping Photosynthesis." Bring the reading with you to the next class meeting.

Activity: Mapping Photosynthesis

Below are the responses of a prospective biology teacher to three questions on the topic of 'photosynthesis' found on her comprehensive exit exam—which students must pass to receive their degrees. The exam questions are typically graded by a committee of faculty members using a scale of 1-5 points, with a score of 5 being the highest grade possible.

Imagine that you are member of the 'grading committee' and your committee must determine the grade the students should receive for each question. Along with a grade for each question (1-5), the committee provides comments/feedback to students explaining the rationale for the scores. One person on the committee should act as the 'facilitator' for one of the questions, leading the discussion and formulating the group response to that question. Note that all members of the group are responsible for each answer, but the facilitator's role is to lead the discussion and formulate the group's response.

Question:

1. Discuss the structure of the chloroplast with regard to the two major sets of reactions that occur there during photosynthesis. Make sure to include the following components in your answer: granum, light-dependent reactions, thylakoid, stroma lumen, and Calvin cycle. You may include a diagram in your answer to support your discussion.

Student Answer**:** The chloroplast is the site of photosynthesis. Structurally it is divided into two areas: the stroma and the lumen. The light-dependent reactions occur in the stroma, while the Calvin cycle occurs in the lumen. The chloroplasts contain disk shaped structures called 'grana' (plural granum). A stack of grana is a thylakoid.

_____ (Facilitator)

Student Grade (circle one) **1** **2** **3** **4** **5**

Committee's Comments:

Question:

2. Summarize the events of the Calvin Cycle, highlighting the significance of following molecules in the metabolic pathway:

- Glucose
- Ribulose 1,5 bisphosphate (RuBP)
- ATP
- 3-phosphoglycerate (PG)
- NADPH
- Glyceraldehyde 3-phosphate (G3P)
- CO_2

Student Answer: The Calvin cycle is a complex metabolic pathway that results in the production of glucose (and other sugars). Ribulose 1,5 bisphosphate can be thought of as the starting material. Carbon dioxide is combined (fixed) with RuBP forming a six carbon molecule that is unstable and breaks down into 3-phosphoglycerate (3PG). 3PG molecules are phosphorylated (have energy in the form of phosphate added to them from ATP) and reduced (by NADPH) producing Glyceraldehyde 3-phosphate (G3P) which is phosphorylated (has energy in the form of phosphate added to them from ATP) producing RuBP which is put together to make glucose.

_____ (Facilitator)

Student Grade (circle one) **1** **2** **3** **4** **5**

Committee's Comments:

Question:

3. Discuss the products of the light-dependent reactions and the significance of these materials to the production of glucose:

Student Answer: The light-dependent reactions are a complex metabolic pathways in which charged particles (protons and electrons from water) are separated, producing an electro-chemical difference on two sides of a membrane. Electrons are stripped from water molecules and are used to produce the electrochemical difference. In this process, ATP and NADPH and oxygen are produced. The NADPH is cycled back into the light-dependent reactions while the oxygen and ATP enter the Calvin Cycle.

_____ (Facilitator)

Student Grade (circle one) **1** **2** **3** **4** **5**

Committee's Comments:

Instructor Support: Mapping Photosynthesis

Learning objectives:

- Students will assess and assign a grade to a student's description of the events of photosynthesis (evaluation).
- Students will justify their assessments of descriptions of the events of photosynthesis (evaluation).
- Students will evaluate a student's concept maps, classifying student knowledge as accurate, incomplete or containing misconceptions (application).

Guidelines: The 'Pre-Activity' should be assigned prior to the class meeting in which the collaborative activity is to be conducted. Students should read the scenario critically and answer the questions in the pre-activity before coming to class. In the collaborative activity, students assemble in groups of three, with each student serving as the facilitator for one of the three question sets, and acting as a discussant for the others. Some faculty like to assign students into groups while other faculty let students self-assemble. Each group should turn in one sheet containing the group's responses and identifying the group members' roles as facilitator-discussants. The 'Post-Activity' can be assigned upon completion of the collaborative group activity.

Prerequisite topic coverage: This activity is best conducted after coverage of material addressing the events of photosynthesis in your text.

Teaching Tip: Instructors can support student groups by moving around the room and clarifying questions about the activity without answering the questions posed to students in the question sets. At the end of the activity the instructor should engage students in a discussion on the activity, asking selected students to orally present their findings to specific questions. This provides the instructor the opportunity to identify desired/best responses to the questions. Remind students to record their names legibly in the spaces that document their roles as facilitators/discussants.

Collaborative Group Size: Optimal for groups of **three** students.

Time: Collaborative activity should take approximately 30 minutes to complete.

Instructional prep time: Minimal—15 minutes.

Answers Pre-Activity Assignment:

1. d
2. b
3. a
4. a

Answers Post-Activity Assignment:

1. c
2. b
3. e
4. d

Target Responses—Critical Question Set

1. Structure of the chloroplast

Ratings will vary:

Key comments to look for in groups' responses:

- Response should point out inaccuracies regarding the site of the pathways and naming of structures. The chloroplast contains structures called thylakoids that typically form stacked structures called grana. The light-dependent reactions occur along the thylakoid membrane, while the Calvin cycle occurs in the stroma.

2. Summarize the events of the Calvin cycle

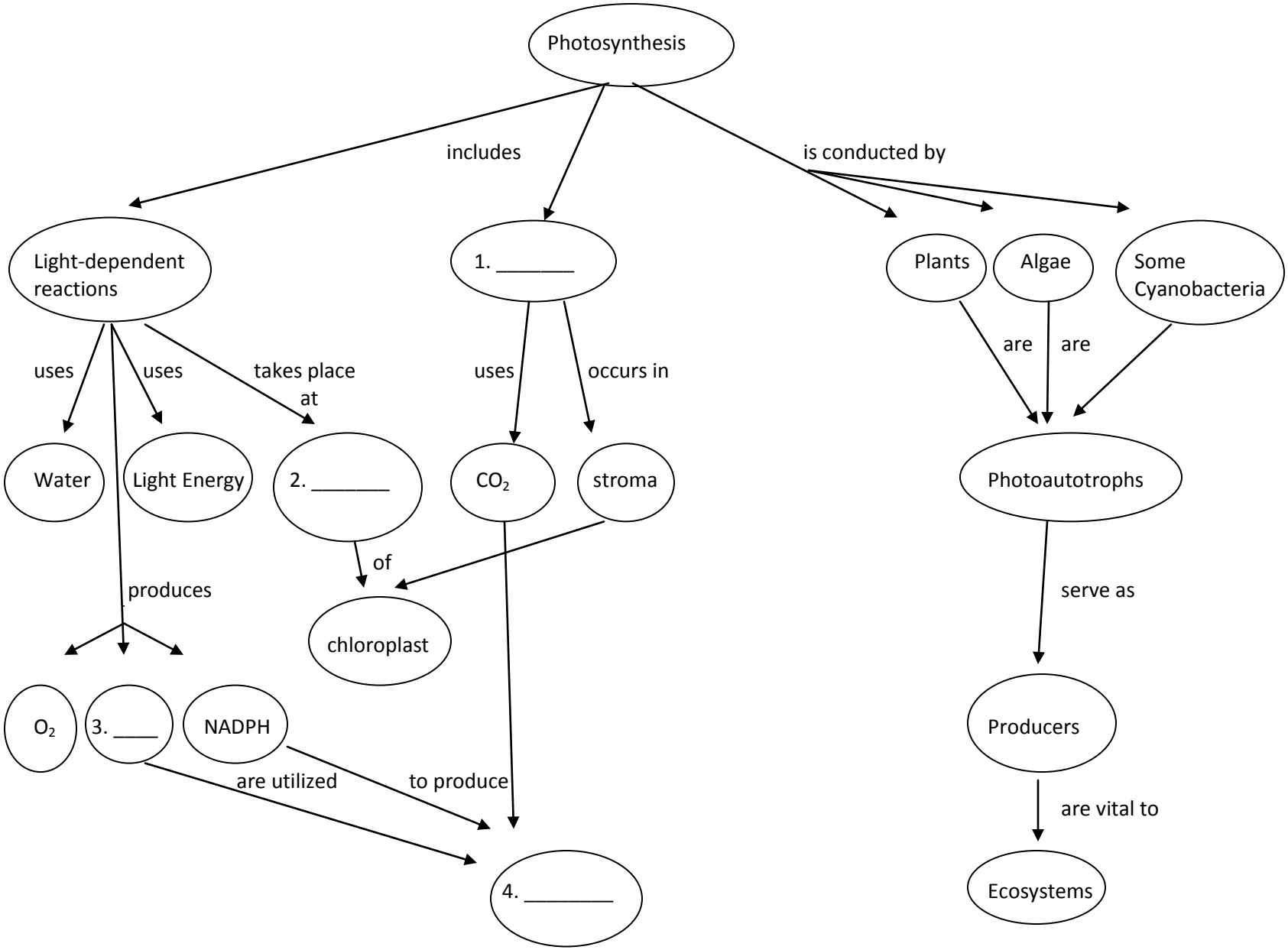
Ratings will vary:

- Response should point out a few inaccuracies: Note that some G3P molecules are combined to make carbohydrates (glucose), while others are converted into RuBP.

3. Products of the light reactions

Ratings will vary

- Response should point out that the answer is incomplete, not fully addressing the question, and also contains some inaccuracies. Note that photosystems incorporated into the thylakoid membrane produce NADPH, ATP and O_2. The O_2 is released into the atmosphere, while the NADPH and ATP are utilized in the Calvin cycle in the manufacture of carbohydrates.


Photosynthesis
includes
is conducted by
Light-dependent reactions
1. _____
Plants
Algae
Some Cyanobacteria
uses
uses
takes place at
uses
occurs in
are
are
Water
Light Energy
2. _____
CO_2
stroma
Photoautotrophs
of
produces
chloroplast
serve as
O_2
3. ____
NADPH
Producers
are utilized
to produce
are vital to
4. _____
Ecosystems

Post-Activity Assignment: Mapping Photosynthesis

Name _____

Consider the attached concept map making note of the four incomplete concepts (labeled 1-4). Complete the map by supplying appropriate concepts in blanks 1-4 using the terms below as options for each blank.

1. Concept choices:
   a. Citric acid cycle/Krebs cycle
   b. Photorespiration
   c. Calvin cycle
   d. Chemiosmosis
   e. Fermentation

2. Concept choices:
   a. Mitochondrial matrix
   b. Thylakoid membrane
   c. Stroma
   d. Stomata
   e. Bundle sheath cells

3. Concept choices:
   a. Glucose
   b. Ribulose biphosphate (RbBP)
   c. Glycolate
   d. PEP carboxylase
   e. ATP

4. Concept choices:
   a. Nucleic acids
   b. Proteins
   c. Lipids
   d. Carbohydrates
   e. ATP

Mapping Photosynthesis

An Active-learning Exercise

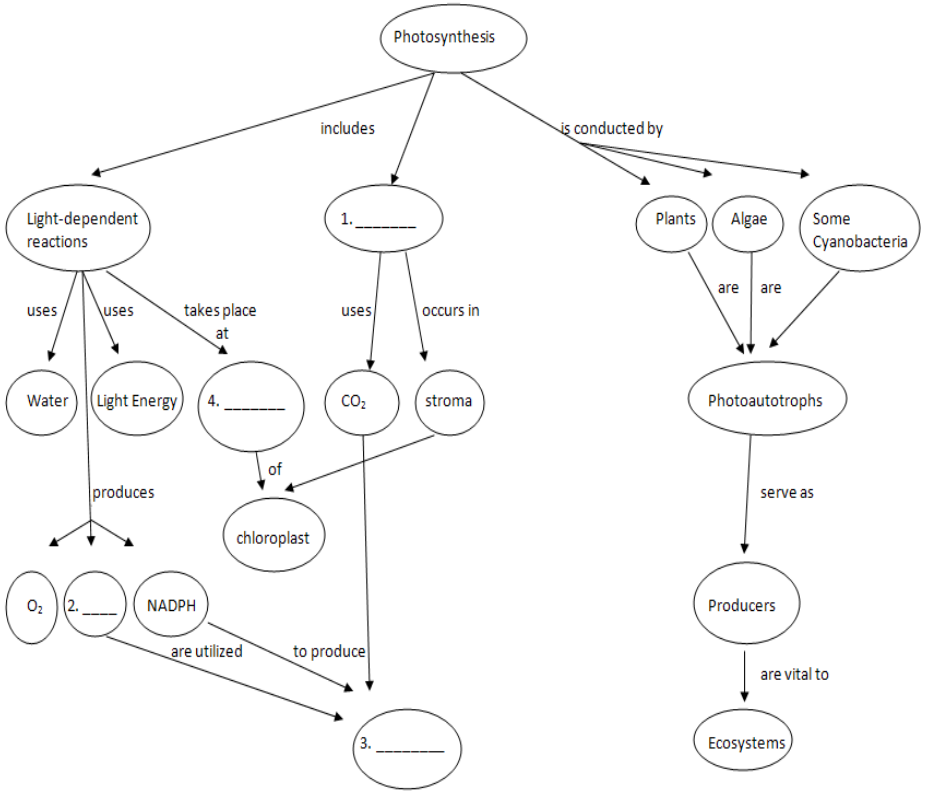
Objectives

- During this activity you will:
  -Assess and assign a grade to student descriptions of the events of photosynthesis (evaluation).

  -Justify your assessments of descriptions of the events of photosynthesis (evaluation).

‘Mapping’ Photosynthesis

Concept Maps



Discussion Questions

- Structure of the chloroplast
- Products of Light-dependent reactions
- Events of Calvin cycle

Activity Guide

- Work in groups as assigned to discuss and answer question sets.
- Different student to act as a **facilitator** for each question set.
  - Lead discussion; formalize group response.
- Each student acts as a **discussant** for other question sets.
  - Provide insights & perspectives; consider, compare & contrast inputs of others as you collaborate to form group response.
- You may be called on to present your group's answers to class.