Energy Processing

Photosynthesis

Classwork

1. Describe the relationship between the colors of the visible spectrum, their wavelength and the amount of energy they possess.
2. Using your knowledge of "absorption and reflection", explain how our eyes and brain perceive color.
3. Refer to the graph showing the Absorption Spectrum of chlorophyll a and chlorophyll b. Interpret the wavelengths of light that show the great amount of absorbance for chlorophyll a and chlorophyll b.
4. Describe three ways pigment molecules can release the energy gained from a photon.
5. In 1877 Albert Frank used the term symbiosis to describe a long term interaction between two or more biological species. Discuss the evidence that supports endosymbiosis.
6. The light reaction of photosynthesis occurs in the thylakoid membrane. Briefly outline the events that occur during this reaction.
7. Melvin Calvin and Andrew Benson discovered the Calvin cycle using radioactive carbon. The Calvin cycle is also called "Carbon fixation". Explain what this term means, and where the Calvin cycle occurs in the plant cell.
8. If water labeled with ^3H is added to a suspension of photosynthesizing chloroplasts, which of the following compounds will first become radioactive: ATP, NADPH, O_2 or glyceraldehyde 3-phosphate?

Homework

9. In the fall deciduous tree leaves start turning bright colors such as orange, red and yellow. As the tree gets ready for the approaching winter it stops making chlorophyll and we are able to see the accessory pigments. What role do the accessory pigments play in photosynthesis?
10. Adenosine triphosphate was discovered in 1929. ATP is the main energy source for living organisms. Briefly explain how ADP becomes ATP.
11. Membrane proteins known as photosystems have an important role in ATP production. Briefly explain how they are used to generate ATP.
12. Purple sulfur bacteria only use a single photosystem to continue to recycle electrons. Describe the path of the electrons, and explain the disadvantages of cyclic electron flow.
13. A plant is unable to obtain water. Describe where this will affect photosynthesis of the plant; be specific of the reaction that is affected.
14. In the equation for photosynthesis, where does the oxygen come from: the carbon dioxide or the water?
15. Knowing the chemical reaction of photosynthesis can be useful in understanding where the individual molecules react. Write the reaction, and then describe how and where they are broken down or made during photosynthesis.
16. If CO_2 is labeled with ^{14}C is added to a suspension of photosynthesizing chloroplasts, which of the following compounds will first become radioactive: ATP, NADPH, O_2 or glyceraldehyde 3-phosphate?

Resource Acquisition – Photosynthesis

Classwork

17. Roots play a vital role in helping the plant obtain nutrients. Describe 2 other functions of the root system. What is the significance of the root hairs?

18. Stems contain areas where side branches and leaves develop. Describe two types of bud, also include the terms: internode and node.
19. Water loss can easily cause plant death. Discuss how the stomata work.
20. Auxin is a plant hormone that affects plant growth. Explain how and where this hormone works in a plant.
21. Corn stunt virus causes a great reduction in the growth rate of infected corn plants, so the diseased plants take on a dwarfed form. Since their appearance is reminiscent of a genetically dwarfed corn species, you suspect the virus may inhibit the synthesis of gibberellins by the corn plants. Describe an experiment you might conduct to test this hypothesis.

Homework

22. Draw and label the root cap, include the meristem, zone of elongation, and zone of maturation.
23. If a plant were to take in salty water, what effect do you think this would have on the stomata guard cells?
24. Many plants have a waxy coating on the top of the leaf and the stomata on the underside of the leaf. Explain why this is beneficial to the plant.
25. Transpiration exerts a powerful pulling force on the water column in the xylem. When would you expect transpiration to proceed most rapidly? Why? Describe the source of the pulling force.
26. Draw and label a cross section of a leaf. Include upper and lower epidermal cells, spongy mesophyll, guard cells, and stomata.
27. Discuss how temperature is related to the presence carbon dioxide, oxygen, and water vapor in a leaf.
28. Explain the behavior of phototropism; include the role of auxin in this phenomenon.
29. A gardener grows tomatoes in her back yard. Everyday she goes out and pinches off the axillary buds. What effect does this have on the plant and tomatoes?
30. Gibberellins and cytokinins are two important plant hormones. Discuss how each affects plants growth and development. Are they either natural or artificial hormones?

Cellular Respiration

Classwork

31. Glycolysis is a metabolic pathway that literally means sugar splitting. Provide an overview of the investment and payoff for glycolysis, include where it occurs in the cell.
32. Fermentation will occur if there is no oxygen present. Describe the two types of fermentation and what conditions would cause them to occur.
33. You may have learned it LEO- (loose electrons oxidation) GER -(gain electrons reduction) OR – OIL- oxidation is loss) RIG -(reduction is gain), either way cell respiration and photosynthesis are called REDOX – (reduction/oxidation) coupled reactions. Using the formula for photosynthesis, describe what is being reduced and what is being oxidized.
34. Aerobic respiration requires oxygen. Briefly describe the three stages involved in the entire process.
35. The mitochondria are also believed to have once been a prokaryote living on its own. What evidence do we have to support this theory? Describe the interior of the mitochondria.
36. Muscle cells contain many more mitochondria that other tissues in the body. Hypothesize why this is the case.

Homework

37. The citric acid cycle proceeds as long as oxygen is present after glycolysis. Give a tally of what was made during glycolysis, then what was made during the citric acid cycle.
38. Describe the two steps of oxidative phosphorylation.
39. Distinguish where the citric acid cycle occurs and where oxidative phosphorylation occurs in the mitochondria.
40. What molecule is the final electron acceptor following chemiosmosis, and what molecule is formed?
41. Our final count was 32 ATP, 30 from Krebs, and oxidative Phosphorylation, and 2 from glycolysis. However, during the formation of acetyl-CoA we can account for each pyruvate losing a CO2 and forming 2 NADH. How many additional ATP do we get from each NADH?
42. Billy goes out for the football team, and after his 5 sprints grabs his leg in pain from a cramp. Using your knowledge of cell respiration, explain what is happening at the cellular level.

Resource Acquisition – Cellular Respiration

Classwork

43. The respiratory system provides a means for taking in oxygen and getting rid of carbon dioxide. Explain why they surface must be kept moist.
44. The smallest structure where gas exchange occurs is known as the alveoli. Explain what the brain uses as a signal for changing the rate of gas exchange.
45. Describe the differences between open and closed circulatory systems.
46. The human body contains roughly 5 liters of blood. Describe the components that make up the blood.
47. Insects and other arthropods do not have blood like mammals. What kind fluid do they have to move oxygen and nutrients through the body? Do they have an open or closed system?
48. Describe the movement of blood through the: 2, 3, and 4 chambered heart.

Homework

49. Discuss, in detail, how the reactants of cellular respiration reach a human skin cell.
50. Explain the effect of carbon monoxide on the body.
51. A sudden and massive loss of blood results in a decrease in blood pressure. Describe mechanisms for returning blood pressure to normal.
52. Describe the effect of decreasing the pH of human blood. What would cause this decrease?
53. Fetal hemoglobin has a greater affinity for oxygen than adult hemoglobin. Explain the physiological significance of this difference.
54. Terrestrial vertebrates use more energy in locomotion than aquatic organisms such as fish. How does this disparity fit in with the evolution of the vertebrate cardiovascular system?

Bioenergetics

Classwork

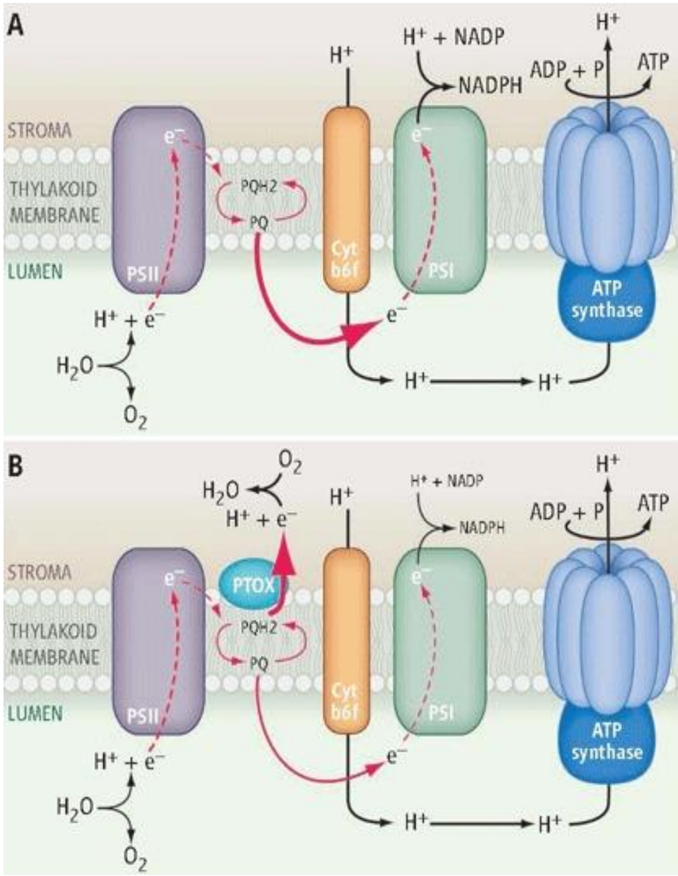
55. “heat, within”, that is the Greek meaning of the word Endotherm. Describe the adaptation these organisms have evolved to maintain constant body temperature.
56. Ectotherms need the heat to warm their body temperature. Describe the disadvantage of being an animal that is cold blooded.
57. Describe how body size and metabolic rate relate to one another.

58. Heat loss is a serious concern for small warm-blooded animals. Think of a small warm blooded animal, and describe key body features it has evolved to maintain its body temperature.

<u>Homework</u>

59. Lizards are ectotherms, why are only few nocturnal?
60. Given two animals, one is an endotherm and the other is an ectotherm. They are about the same body mass. Explain which one would have a higher metabolic rate.
61. If the major adaptation of endotherms to cold climates is their insulation, how would you compare the cold adaptations of a polar bear and a seal?
62. Which environment would be more dangerous to an endotherm: one above its upper critical temperature or one below its lower critical temperature? Why?

Free Response



1. To maximize efficiency, the rate of light harvesting at PSII has to equal the rates of electron transfer from water to the PSI reaction center. If electrons are not transferred fast enough, the gateway between light harvesting and electron transfer in PSII is closed or reduced. Given that single-celled algae cannot easily escape high light intensities, photodamage occurs if the electrons are not shunted to another acceptor. Various organisms take advantage of PTOX as an electron valve between PSII and PSI (Figure B). PTOX only requires 2 iron molecules (compared with 6 for cytochrome b6f and 12 for PSI), allowing the cells to survive in low-iron environments. When necessary, linear electron flow is reduced, and the electrons are transferred from PSII through PTOX back to O_2 in a closed loop, reducing the electron flux to the Calvin cycle and consuming O_2. These alternate electron flows provide ecological advantages for organisms in the high-light, low-nutrient environment of the open ocean.

Photosynthesis in the Open Ocean
Jonathan P. Zehr and Raphael M. Kudela Science 13 November 2009: **326** (5955), 945-946.

a) How is the alternative pathway (B) different from conventional photosynthesis (A)?
b) Which pathway would lead to the production of more carbohydrate (glucose sugar)? Discuss your rationale.
c) Why would the alternative pathway be advantageous to photosynthetic organisms in the open ocean?
d) Explain why the alternative pathway is a long-term or short-term energy processing strategy.

2. Over billions of years, the earth's atmosphere has changed composition due to various geological, climatological, and biological phenomena. The atmospheric concentration of oxygen over the last billion years can be seen in fig. 1.

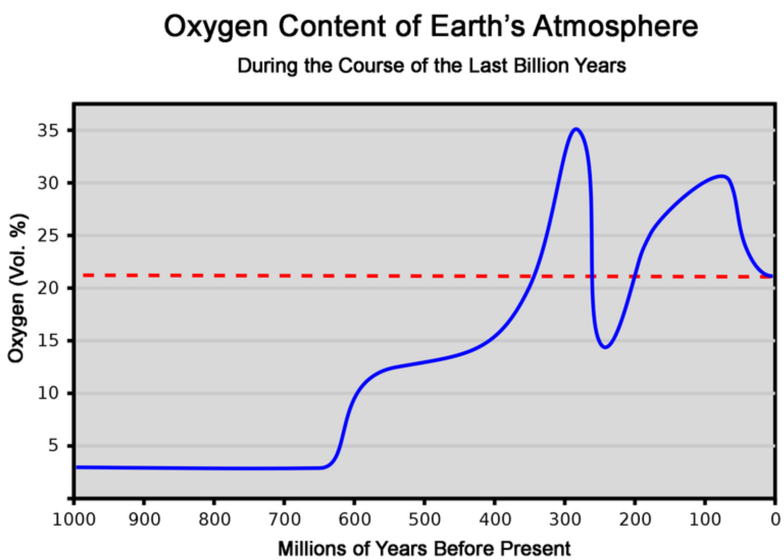
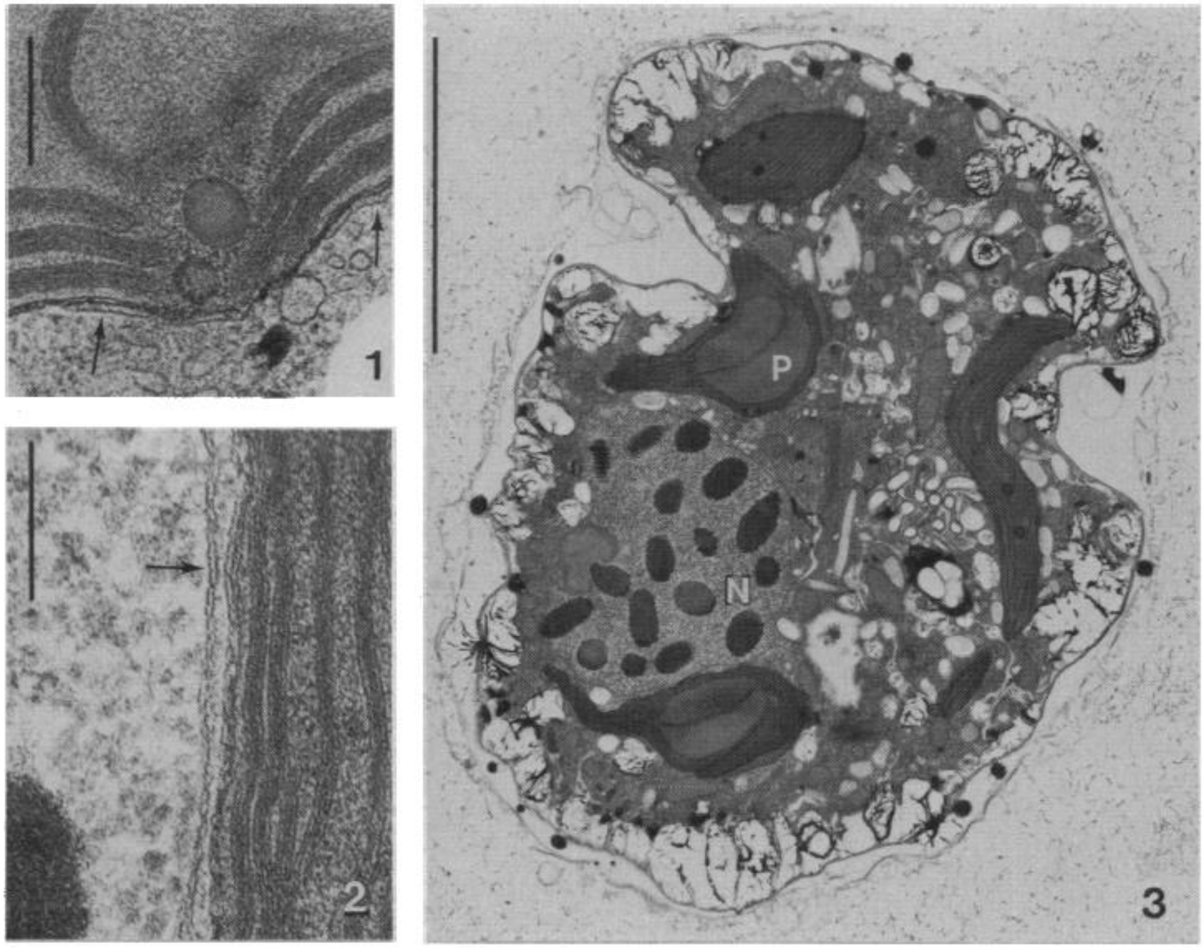


Fig. 1

a. Describe how the change around 600 million years ago in atmospheric oxygen was caused by an earlier change in the primary source of free energy for organisms on Earth.
b. Explain how this change was accelerated by the compartmentalization of reactions in photosynthetic organisms.
c. In the form of a flow chart, clear and labeled diagram, or well-written paragraph, describe how electrons facilitate the production of oxygen in photosynthesis.

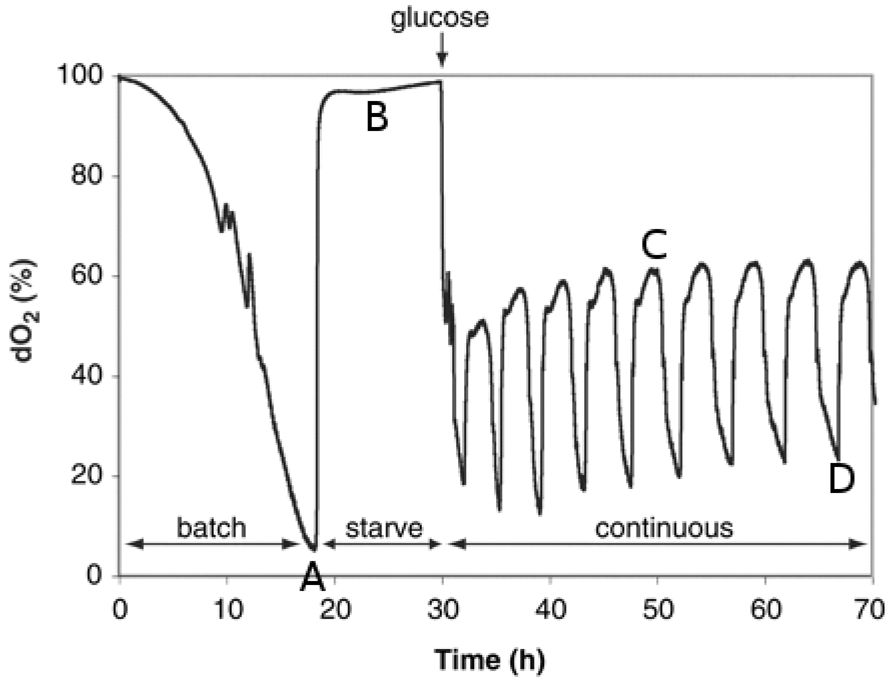


Dinoflagellate with Blue-Green Chloroplasts Derived from an Endosymbiotic Eukaryote
LEE W. WILCOX and GARY J. WEDEMAYER Science 11 January 1985: **227** (4683), 192-194.

3. The chloroplasts of red and green algae (and higher plants) evolved from photosynthetic, prokaryotic endosymbionts. These chloroplasts are surrounded by an envelope consisting of two membranes. With few exceptions, the chloroplasts of other photosynthetic eukaryotes are bound by either three membranes (euglenoids and dinoflagellates) or four membranes (chlorophyll c-containing organisms other than dinoflagellates). It has been proposed that these chloroplasts resulted from the acquisition and degeneration of of endosymbiotic eukaryotes. In Fig.1, the transmission electron micrograph show the three bounding membranes of a blue-green chloroplast indicated by arrows in the dinoflagellate, *Amphidinium wigrens*. The electron-opaque contents of the thylakoids are visible. Scale bar, 0.25 µm. Fig. 2 shows the chloroplast adjacent to the nucleus: showing the nuclear envelope (arrow) and the three membranes of the chloroplast envelope lying next to it. Scale bar, 0.25 µm. Fig. 3 shows a longitudinal section of an *A. wigrense* cell showing its nucleus and profiles of several of this cell's seven chloroplasts. The fibrillar material external to the cell is a mucilaginous (gummy) substance released from peripheral vacuoles upon fixation (cell preparation for electron microscopy). N, nucleus; P, pyrenoid (where carbon fixation takes place); scale bar, 5µm.

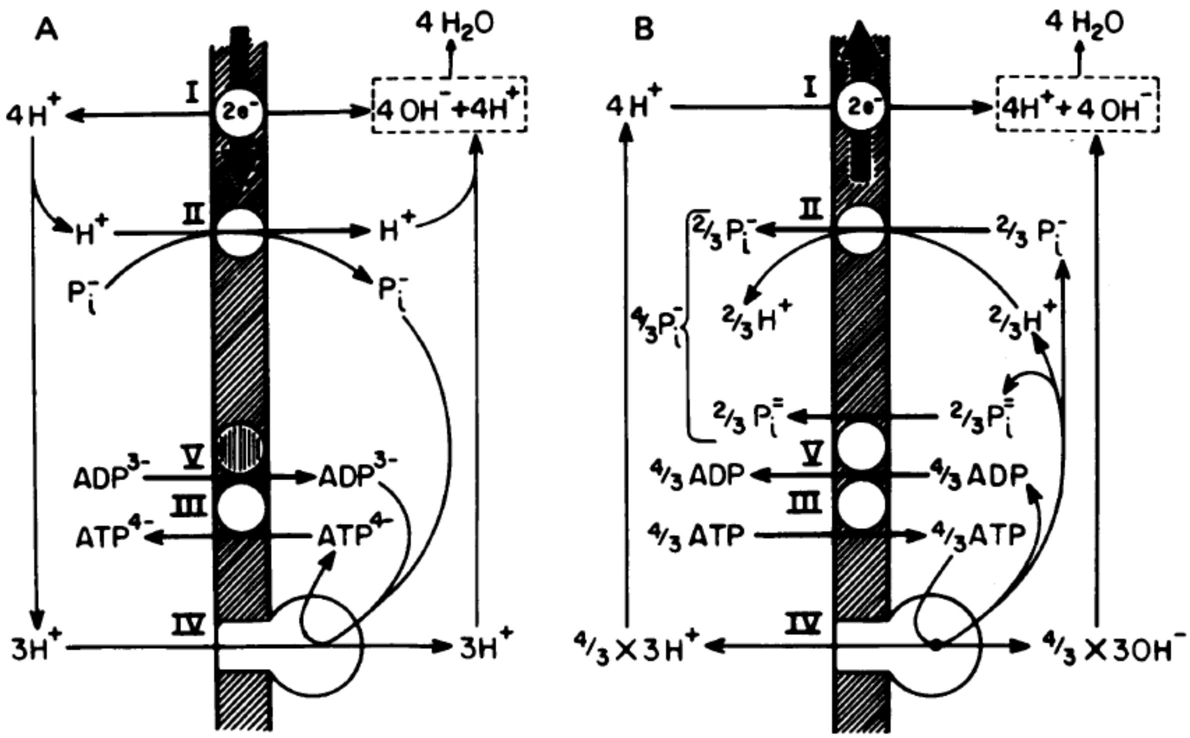
a) Why do organisms such as the dinoflagellate need chloroplasts?
b) How are the chloroplasts of the dinoflagellate different from the chloroplasts of plants and relate organisms such as red and green algae?

c) How do the chloroplasts of *A. wigrense* support the theory of endosymbiosis with a photosynthetic eukaryote rather than a photosynthetic prokaryote?
d) If a cell was to use *A. wigrense* as an endosymbiont, how many membranes would eventually be found surrounding the new organism? Explain your reasoning.



3. The metabolic cycle of yeast. During batch mode, the cells are grown to a high density and then starved for at least 4 hours. During continuous mode (arrow), media containing glucose is introduced to the culture at a constant dilution rate (0.09 to 0.1 hours). dO_2 refers to dissolved oxygen concentrations (% saturation) in the media.
Logic of the Yeast Metabolic Cycle: Temporal Compartmentalization of Cellular Processes
Benjamin P. Tu, Andrzej Kudlicki, Maga Rowicka, and Steven L. McKnight
Science 18 November 2005: 310 (5751), 1152-1158

a) Why does $d0_2$ decreased to near 0% of saturation while yeast cells grow in batch mode?
b) Why would anaerobic respiration (fermentation) happened or not happened during the starvation interval of growth?
c) Why does dO_2 decrease when glucose is added to the media?
d) Where would you expect the population size of the yeast to be greatest and least: point A, B, C, and D? Explain your choice.



Baltazar Reynafarje and Albert L. Lehninger
An alternative membrane transport pathway for phosphate and adenine nucleotides in mitochondria and its possible function
PNAS 1978 75 (10) 4788-4792

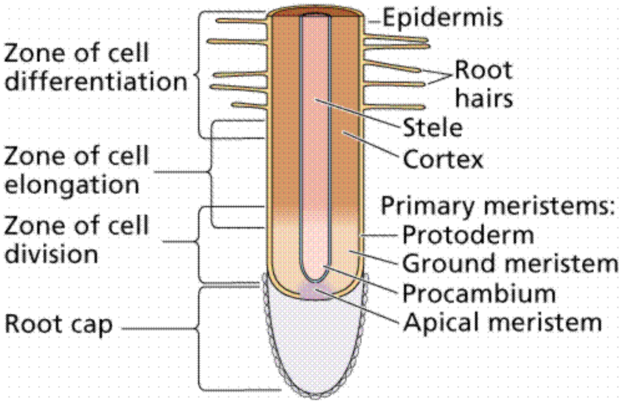
4. The diagram shows vectorial (directional) representations of the transport processes and stoichiometry (relative amounts of chemicals) of (A) oxidative phosphorylation and (B) ATP-dependent reverse electron flow through energy-conserving site 1 of the respiratory chain. Oxidative phosphorylation of external ADP from cytoplasmic precursors requires the ADP-ATP translocase; inhibition of these carriers causes inhibition of oxidative phosphorylation of cytoplasmic ADP. ATP dependent reverse electron flow (B) is proposed to use the electroneutral ATP-ADP-phosphate exchange and the electroneutral phosphate-H+ carrier, each carrying one-half of the phosphate efflux. In the presence of N-ethylmaleimide (a chemical inhibitor of the ADP-ATP translocase), the ADP-ATP translocase is blocked and only one half of the phosphate formed is released to the medium, via the ATP-ADP-phosphate carrier. This formulation requires that 1.33 molecules of ATP are required to reverse the flow of a pair of electrons through site 1. (2e- = 2 electrons; H+ = protons; P_i = phosphate; OH- = hydroxyl ion)

a) Using diagram A (oxidative phosphorylation), describe how cells recharge their chemical batteries (ATP).
b) In terms of energy usage (production and consumption of ATP), how is the pathway shown on diagram B different from oxidative phosphorylation?
c) Why would the cell need (on occasion) to reverse the electron flow from going to oxygen and ending up in other molecules (proteins, lipids)?
d) If the cell has low ATP concentrations within the cell, why would the cell favor oxidative phosphorylation or ATP dependent reverse electron flow?

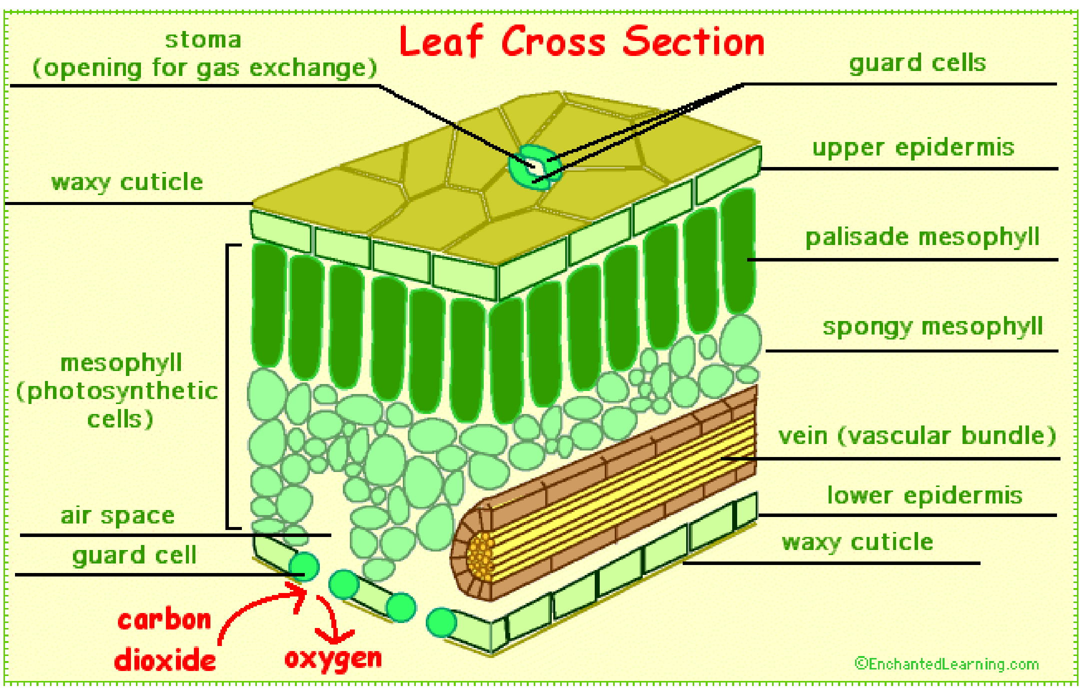
Answer Key

1. The colors are Red, Orange, Yellow, Green, Blue, Indigo, and Violet. Their wavelength varies from 400 to 700 nm. Longer wavelength corresponds to less energy. Shorter wavelength has higher energy.
2. When visible light strikes an object, the object absorbs some of the wavelengths. The wavelengths that are not absorbed are reflected back to our eyes. Our brains interpret the spectrum reflected to our eyes.
3. Chlorophyll a – about 425 nm and 680 nm, chlorophyll b- about 480 nm and 625 nm.
4. (1) Fluorescence- the excited electron releases its energy as photon as it drops to its ground state. (2) Reaction initiation – the excited electron provides activation energy necessary for start a chemical reaction. (3) Resonance transfer – Energy is transferred to nearby pigment molecules without releasing the photon.
5. Both chloroplasts and mitochondria have their own DNA that is circular. On electron micrograph, we see pictures of smaller plastids being engulfed by larger cells, giving them double membranes.
6. (1) In photosystem II, light excites the pigments and electrons move down the electron transport chain. (2) A water molecule is split, giving its electrons to the photosystem. (3) Hydrogen protons are moved from the stroma into the thylakoid lumen. (4) Photosystem I re-excites the electrons, which reduces NADP to NADPH. (5) The protons inside the lumen will move through ATP synthase, creating ATP. (7) Both ATP and NADPH will be used in the Calvin cycle.
7. As carbon dioxide enters the Calvin cycle, it is attached to Rubisco. With the help of ATP and NADPH, the molecule is rearranged to G3P. Thus, it is "fixed" from a gas to a solid sugar. This process takes place in the lumen of the chloroplast.
8. NADPH
9. Accessory pigments allow the plant to absorb a wider range of wavelength to be used to excite electrons.
10. A Phosphate molecule has a negative charge and is to be added to ADP, which also has a negative charge. In order to accomplish this, a lot of energy is needed to attach the third phosphate. This energy is stored in a high-energy bond between the second and third phosphate.
11. Photosystems absorb light energy, which excites electrons to a higher energy level. These excited electrons are able to transfer H+ into the cell. This H+ gradient is then used by ATP synthase to turn ADP to ATP.
12. The electrons are returned to the pigments after proton transport. This is inefficient because ATP is being released outside the membrane. In addition, these organisms need a constant source of light since ATP is not storage of energy.
13. A water molecule is split during the light reaction. The electrons are used to replace electron that are excited by photons of light. The hydrogens help establish a proton gradient. Oxygen is a byproduct and released into the atmosphere.
14. The oxygen comes from the water.
15. $6 CO_2 + 6 H_20 \rightarrow C_6H_{12}O_6 + 6 O_2$. Water is split in the light reaction; at the thylakoid membrane, the H is used to establish a gradient and the O_2 goes into the atmosphere. CO_2 enters the Calvin cycle in the stroma. Glucose is made as ½ a molecule called G3P during the Calvin Cycle in the stroma.
16. G3P
17. Roots also anchor the plant, and store food. The root hairs increase surface area for the uptake of water and minerals.
18. Two types of buds are terminal buds found on the top of plants and axillary buds found at each point of attachment for a leaf.

19. The stomata have two guard cells on either side of the opening. Each guard cell fills its central vacuole when water is plentiful. This causes an opening in the stomata. When water is scarce, the vacuole loses water and the stomata deflate and push against one another.
20. The terminal bud releases this hormone. Auxin inhibits growth from the lateral buds.
21. Answers will vary. Test for the concentration of gibberlins in infested plants. Compare concentrations of gibberlins in infested plants with that of dwarf corn and full size corn plants.
22. A sketch of a root:



23. Water would diffuse out of the guard cells closing the stomata.
24. The waxy coating helps prevent water loss as the sun hits the top of the leaf. Having the stomata on the underside also helps prevent evaporation.
25. Transpiration will occur most rapidly in daylight under moderate temperatures and low humidity. This occurs because the leaves are undergoing photosynthesis and utilizing water to replenish electrons used in the light reactions. The cohesive properties of water allow water evaporating through the stoma to pull water up the xylem of the plant.
26. A sketch of the leaf such as:



27. As the sun heats up the leaf photosynthesis increases, this causes more CO_2 to be used, more O_2 produced, and more water vaporized, all of which caused increased diffusion through the stomata.
28. Phototropism is a plant's response to light. Plants will grow or bend towards a light source. This is caused by the release of the hormone auxin. Auxin will be in greater concentration on the dark side of plant growth.
29. By pinching off the axillary buds the plant will send its nutrients to the terminal bud and get taller, it will also send more nutrients to the tomatoes growing on the vine.
30. Gibberellins lengthen the internodes in plants; they also stimulate growth in germinating seeds. Cytokinins promote cell division in roots and shoots of plants, and slow the aging of plants. They are both natural plant hormones.
31. Glycolysis occurs in the cytoplasm of the cell. It is a catabolic process that occurs without oxygen. 2 ATP are invested and 4 ATP are produced, for a net of 2 ATP. In addition 2 NADH are produced and 2 pyruvate.
32. Following glycolysis, if no oxygen is present, the NADH and pyruvate will be converted to one of two products. Animals will produce lactic acid, and bacteria and yeast will produce ethanol.
33. H20 is oxidized, CO_2 is reduced.
34. (1)glycolysis – splitting of glucose into 2 pyruvic acid in the cytoplasm. (2) Krebs is the stripping of electrons from the pieces of the glucose molecule in the mitochondria (3) oxidative phosphorylation – using the electrons to set up a concentration gradient and form ATP in the mitochondria.
35. Mitochondria have their own DNA. The interior of the mitochondria has a double layer. In between the outer and inner membrane is known as the inter membrane space. The inner membrane has many folds called cristae to increase surface area. The middle of the inner membrane is called the matrix.
36. Muscles do a tremendous amount of work and require more energy than other tissues. Therefore they have more mitochondria for more cell respiration.
37. During glycolysis: 2 ATP, 2 NADH, 2 Pyruvate. During the citric acid cycle: 2 ATP, 6 NADH, $2FADH_2$ and 4 CO_2.
38. (1) The electron transport chain uses energy in the electrons to establish a gradient. (2) Chemiosmosis as protons flow down the concentration gradient through the ATP synthase, each NADH makes 3 ATP and each $FADH_2$ makes 2 ATP.
39. The citric acid cycle occurs in the matrix, and oxidative phosphorlation occurs in the inner membrane.
40. Oxygen is the final electron acceptor, and water is the final product.
41. For each NADH, we get 3 ATP for a total of 6.
42. There is not enough oxygen going to the leg muscles, so they begin lactic acid fermentation. This is what causes the pain.
43. The surface must be kept moist because the gases must be dissolved in water before diffusing across the alveolar surfaces into the blood stream.
44. The brain monitors carbon dioxide levels using the pH of the blood. As carbon dioxide levels rise the pH will drop.
45. Closed circulatory systems contain vessels to circulate the blood through. These vessels connect to heart in loop. The heart pushed the blood through the vessels. An open circulatory system pumps the circulatory fluid directly into the spaces between the organs. There is no distinction between the circulatory fluid and interstitial fluid.
46. Blood consists of plasma, the liquid matrix, erythrocytes (red blood cells) that transport oxygen, and leukocytes (white blood cells) that fight infection.
47. They have hemolymph and an open circulatory system.

48. (2 chambered heart) – blood travel from the atrium into the ventricle, to the gills for gas exchange, then through the body. (3 chambered heart) – blood leaves the right ventricle to the lungs for gas exchange, back to left atrium, to single ventricle then to body or back to lungs, and back to heart again. (4 chambered heart) From the body to right atrium, to rt. Ventricle, to the lungs for gas exchange, to the left atrium, to left ventricle to body and back to right atrium.
49. Deoxygenated blood enters the right atrium where it flows into the right ventricle. The right ventricle pumps the blood to the lungs. Oxygen diffuses into the body through the aveoli of the lungs. The gas diffuses into the blood stream and the oxygenated blood flows into the left ventricle where it is pumped through the left atrium to the body. From here it travels through the arteries to the capillaries for diffusion to the skin cell. Glucose also arrives at the skin cell via the blood supply. Most food digestion and absorption occurs in the small intestine. Enzymes reduce food particles to their constituent monomers (nucleotides, amino acids, glucose) which enter the blood stream through carrier proteins (mainly) in the microvilli of the intestinal wall. Blood transport these nutrients to the skin cell for cellular respiration.
50. Hemoglobin has four binding sites for carrying gases in the blood. These sites have a higher affinity for carbon monoxide than for oxygen. When one of the binding sites is occupied by a carbon monoxide molecule, the resulting complex, called carboxyhemoglobin, has an increased affinity for oxygen molecules. As a result, oxygen does not dissociate in oxygen-poor tissues, preventing cellular respiration and causing cell death.
51. Blood pressure can be returned to normal (after bleeding has been stopped) by increasing intake of water. The water will diffuse into the blood stream increasing pressure. Another method is to increase the intake of salty foods. High salt concentration in the blood increases the diffusion of water into the system, increasing the pressure.
52. Decreasing the pH of the blood causes an increase in respiration to expel excess carbon dioxide and increase the intake of oxygen. This decrease is usually the result of high carbon dioxide concentration, which has dissociated to carbon acid, but can also be caused by a build up of lactic acid (lactic acid fermentation).
53. Fetal hemoglobin has a high affinity for oxygen than adult hemoglobin to allow it to “steal” oxygen from the mother’s blood supply.
54. Terrestrial vertebrates have a greater need for energy and thus have adapted more efficient circulatory systems for transport the necessary reactants for cellular respiration. The 3- and 4-chambered hearts allow blood to be delivered through the body at a high pressure than the 2-chambered fish heart.
55. They have adaptation such as hair, fur, feathers and fat to help prevent heat loss.
56. These animals are more vulnerable to prey, due to sluggish movement caused by lack of heat. They must rely on environmental factors to supply heat.
57. There is an inverse relationship between body size and metabolic rate. As the size of the animal increases its metabolic rate decreases.
58. Answers will vary, but should include physical description of the animal that is advantageous to retaining heat.
59. Lizards are ectotherms; they generally require heat to raise their metabolic activity. There is very little heat at night.
60. The endotherm has a higher metabolic rate; it takes more energy to maintain a constant body temperature.
61. Polar bears have adapted with heavy fur coats while seals have a thick layer of blubber (fat) under the skin. Both adaptations serve the same purpose: to keep the animal warm.

62. An environment above the endotherm's upper critical temperature is more dangerous. At lower temperatures, endotherm can burn additional energy to keep warm but at high temperatures there are limited mechanisms for cooling down.

1. Photosynthesis in the open ocean.
    a. Excited electrons in photosystem II are passed to PTOX through PQ and are kept from following the conventional route of electrons in noncyclic photosynthesis. The final electron acceptor is oxygen, which becomes water along with 2 H+ ions.
    b. Conventional photosynthesis (Figure A) will produce more carbon fixation due to the increased flow of electron to NADP and the increase of the hydrogen ion gradient that the ATP synthase can use to produce more ATP. ATP and NADPH are needed for the Calvin cycle to produce one of the precursor to all macronutrients: carbohydrates, amino acids, and lipids.
    c. Since iron is hard to come by in the open ocean, microorganisms might have nutrient deficits that do not allow them to build the electron transport mechanism of conventional photosynthesis that require larger amounts of iron than the alternative pathway. Also, sunlight excited electrons must be used to lower their energy levels or they will create radical damage to other macromolecules, destroying the cells. The PTOX pathway allows them to safely pass electrons to oxygen to prevent the electron damage that may result.
    d. The alternative energy processing pathway of PTOX would be a short-term strategy to prevent photodamage or free radical damage to the cell and to conserve iron when the mineral is scarce. Since the PTOX system reduces the level of ATP and Calvin cycle production, it cannot be used long-term or the cell will not have energy to function or nutrients to grow and divide.

LO 2.4 The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store and use free energy. [See **SP 1.4, 3.1**]
LO 2.5 The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy. [See **SP 6.2**]
LO 2.1 The student is able to explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow and to reproduce. [See **SP 6.2**]
LO 2.2 The student is able to justify a scientific claim that free energy is required for living systems to maintain organization, to grow or to reproduce, but that multiple strategies exist in different living systems. [See **SP 6.1**]
LO 2.3 The student is able to predict how changes in free energy availability affect organisms, populations and ecosystems. [See **SP 6.4**]

2. Oxygen Content Earth's Early Atmosphere.
    a. Prior to the evolution of photosynthesis, organisms used chemical free energy. They were either chemoautotrophic, relying on inorganic chemicals to produce food or later on, chemoheterotrophic, breaking down glucose and storing the energy in the form of ATP. Oxygen was not produced in either of these cases. With the advent of photosynthesis, light became the primary source of free energy. Its capture allowed the conversion of inorganic materials into glucose which could then be used to form ATP. Oxygen was produced in this process as water was hydroylyzed to replenish electrons removed from the enzyme complex critical to the photosynthetic process. As photosynthetic organisms flourished, the level of oxygen in the atmosphere increased. (note: initial free oxygen was

spent in oxidizing iron and so levels of O_2 in the atmosphere did not begin to rise until much later than the evolution of photosynthetic bacteria.

b. Chloroplasts are an efficient light capturing structure. Their double membranes make it possible to gather photons, and store this energy in ATP through a chemisomotic process made possible only in the chloroplasts compartments. This is dependent upon a hydrogen ion gradient that is formed within the thylakoid structures of chloroplasts. The ATP generated (along with NADH) can then be used to power the production of glucose. The efficiency of this process requires the hydrolysis of water which releases oxygen as a by-product, adding much more free oxygen to the atmosphere than was possible before the advent of double-membrane based photosynthesis.

c. Photon energy → stimulated electrons in PS I and II → resonance transfer of electron energy → ejection of electron from PS then:→ capture of electron energy by proton pump → capture of electron by NADP+and in parallel, water is hydrolyzed to produce an electron to replace that lost by the PS → oxygen (and H+ and electrons) is produced as a result

LO 2.1 The student is able to explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow and to reproduce. [See **SP 6.2**]

LO 2.2 The student is able to justify a scientific claim that free energy is required for living systems to maintain organization, to grow or to reproduce, but that multiple strategies exist in different living systems. [See **SP 6.1**]

LO 2.3 The student is able to predict how changes in free energy availability affect organisms, populations and ecosystems. [See **SP 6.4**]

3. Dinoflagellates

   a. Photosynthetic organisms need chloroplasts to use the Sun's energy to increase the quantum levels of electrons in photosystem's I and II and pass those electrons to electron carriers that pump protons into the lumen of the thylakoids and to NADPH; ATP synthase uses the proton concentration gradient to make ATP; ATP and NADPH are used in the Calvin cycle to generate the precursors of carbohydrates, proteins, and lipids.

   b. The chloroplast of the dinoflagellate shown in the figures has 3 membranes surrounding the organelle, while plant-like organisms have chloroplasts with two membranes.

   c. The theory endosymbiosis suggests that the mitochondria and chloroplasts found in eukaryotes derive (come from) prokaryotes or other simpler cells that were engulfed by the eukaryotes and formed a permanent association through evolutionary selection. If a eukaryote would take in a prokaryote, the organelle formed from the prokaryote would have 2 lipid bilayers surrounding the organelle (the membrane of the engulfing vacuole and cell membrane of the prokaryote); the presence of an extra membrane around the chloroplasts of A. wigrense implies that an ancestor took in another eukaryote that also had undergone a prior endosymbiotic process in its life history.

   d. If A. wigrense would be used as endosymbiont by another organism, the new organism would have chloroplasts surrounded by four membranes: the three it already has and the membrane of the phagocytic vacuole.

LO 2.4 The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store and use free energy. [See **SP 1.4, 3.1**]
LO 2.5 The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy. [See **SP 6.2**]
LO 4.4 The student is able to make a prediction about the interactions of subcellular organelles. [See **SP 6.4**]
LO 4.5 The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [See **SP 6.2**]
LO 4.6 The student is able to use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [See **SP 1.4**]

4. The Metabolic Cycle of Yeast
    a. The growing cells need ATP to keep the chemical reactions that keep them alive functioning. In the presence of oxygen, yeast cells can carry out aerobic respiration that requires oxygen to accept the electrons in the electron transport chain and yields the greatest amount of ATP from glucose.
    b. Anaerobic respiration will not occur because there is no or small amount of carbon source (glucose) to yield ethanol, carbon dioxide and ATP.
    c. The cells use oxygen to carry out aerobic respiration. Oxygen is converted into water and glucose is converted into carbon dioxide.
    d. The population or concentration of yeast will be greatest at point D, because they have gone through several cycles of cell division and addition of glucose. The least concentration of yeast cells would be found at point B; the cells are being starved of glucose and cannot generate ATP to run chemical reactions; at the best, the population size is stagnant; at worse, the chemical media becomes hostile to the cells (chemical waste from metabolism), and cells begin to die (irreversible damage occurs to enzymes and DNA).

LO 2.1 The student is able to explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow and to reproduce. [See **SP 6.2**]
LO 2.2 The student is able to justify a scientific claim that free energy is required for living systems to maintain organization, to grow or to reproduce, but that multiple strategies exist in different living systems. [See **SP 6.1**]
LO 2.3 The student is able to predict how changes in free energy availability affect organisms, populations and ecosystems. [See **SP 6.4**]

5. Alternative membrane pathway
    a. The proton pumps of the inner membrane of mitochondria transports protons into the intermembrane (towards the left in diagram A) as the electrons gotten from glycolysis and Krebs cycle flow through the system to oxygen (producing water). The proton gradient is used by the ATP synthase to bring ATP and Pi chemically together to form ATP.
    b. Diagram A shows a pathway that produces ATP, while the process in diagram B consumes ATP. The reverse flow electrons through the protons pumps in the inner membrane of mitochondria require ATP, which is hydrolyzed by ATP synthase.
    c. Anabolic processes need electrons, or reducing power, to make bonds between atoms; therefore, it would be advantageous to the cell to divert electrons to these processes when needed; the process requires the consumption of ATP, but all

anabolic processes require the use of ATP and the electrons from this pathway may be more efficiently given or acquired.

d. The cell would favor oxidative phosphorylation, because ATP will be produced and not consumed. ATP dependent reverse electron flow would cost the cell ATP molecules, worsening the low ATP concentration. Lowering the ATP concentration when the ATP levels are low can endanger the life of the cell.

LO 2.4 The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store and use free energy. [See **SP 1.4, 3.1**]
LO 2.5 The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy. [See **SP 6.2**]
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