Photosynthesis (SC/BIOL 4061) First Term Test (5 Oct 2006)

Answer the following five questions in the exam booklet provided. When finished, please insert the question sheet and your crib sheet(s) in the exam booklet (all will be returned to you after grading). You should be able to answer each question on one to two pages. Excessive length is not encouraged.

Question One

Macrofossil evidence for ‘primordial’ photosynthesis is fairly strong, because living stromatolites were recently discovered that are similar in structure to fossil stromatolites. Describe the structure and function of a modern stromatolite and how it relates to changes in atmospheric conditions over the past 3000 million years or so.

Question Two

Prokaryotic photosynthesis is divided into anoxygenic and oxygenic mechanisms. Describe the properties of photosynthesis shared among and/or unique to prokaryotic anoxygenic photosynthesizers (including the nature and properties of the pigments they use and unique mechanism(s) of carbon dioxide fixation).

Question Three

In the context of the various fates of an absorbed photon, how would increased light intensity affect the fate of an excitation event? Give reasons for your hypothesis.

Question Four

Contrast the two mechanisms of cyclic tetrapyrrole synthesis leading to heme and chlorophyll from the basic precursors.

Question Five

Describe how Emerson and Arnold established the concept of a ‘group’ of chlorophyll molecules participating in oxygen evolution in photosynthesis. What organism did they use for their experiments?

First Term Test KEY

Question One: A description of the stromatolite, noting the layering of organisms, oxygenic and anoxygenic photosynthesizers as well as aerobic and anaerobic heterotrophs (75%). The relation between these different organisms and increasing oxygen levels over *ca* 3000 million year (25%).	
Question Two: The prokaryotic anoxygenic photosynthesizers use bacteriochlorophylls that absorb at wavelengths much longer than the chlorophylls of cyanobacteria and eukaryotic oxygenic photosynthesizers (33%). Electron sources include $H_2S \rightarrow S \rightarrow SO_4^{2-}$ and H_2 (33%). Carbon dioxide fixation pathways include two unusual ones: a reverse Krebs and the hydroxypropionate pathways (33%).	
Question Three: High light intensity will cause more excitation events (20%), saturating photochemistry (20%) so that fluorescence (20%) and heat release (‘radiationless relaxation’)(20%) will increase, as will triplet formation (and thus singlet oxygen and photooxidation)(20%)	
Question Four: Succinyl-CoA and glycine condensed to form delta-ALA in proteobacteria, animals (and plants) for heme synthesis. In cyanobacteria and plant chloroplasts, glutamate is converted to delta-ALA by a t-RNA mediated pathway (60%). Subsequent dehydration of two delta-ALA molecules to form porphobilinogen and deaminations to create the tetra-pyrrole are similar in both pathways (20%), followed by Fe insertion to form heme, and Mg insertion to form chlorophyll (20%).	
Question Five: Under conditions in which oxygen evolution was saturated as a function of light intensity (40%), they examined the dependence of oxygen evolution on chlorophyll concentration, and from the slope of oxygen molecules evolved *versus* chlorophyll concentration, they determined 2480 molecules chlorophyll per oxygen evolved (40%). The organism was *Chlorella* (green algae)(10%).	

Photosynthesis (SC/BIOL 4061) Second Term Test (9 Nov 2006)

Answer the following four questions in the exam booklet provided. When finished, please insert the question sheet and your crib sheet(s) in the exam booklet (all will be returned to you after grading). You should be able to answer each question on one to two pages. Excessive length is not encouraged.

Question One

Describe the structure and kinetics of the reaction centers for Photosystems I and II of higher plants. Include brief descriptions of the possible source(s) of electrons to reduce the Chl^+.

Question Two

In the context of electron (and and in some cases H^+) transport in the light reactions of photosynthesis, describe 4 examples of chemically distinct compounds that mediate their transport.

Question Three

Explain the impact of pH changes during the light reactions on the energetics and kinetics of the chloroplastic ATP synthetase. Would you predict that pH would have a regulatory role? Explain.

Question Four

Contrast three mechanisms of carbon dioxide fixation, two found in prokaryotes and the major one of eukaryotes: both the carboxylase enzyme(s) and the biochemical pathways that ‘recycle’ reactants to allow sustained fixation of carbon dioxide.

Second Term Test KEY

Question One: The composition of the reaction centers are similar core dimers (sites of P_{680} or P_{700}, phaeophytin, quinones and carotene) with some unique components (Fe in PS II, Fe•S in PS I)(40%)[1]. Within the reaction centers, the initial electron transfers are very fast (ps to ns)(20%). The sources of electrons to reduce P_{680}^+ are water, via a tyr•Mn•Ca complex (20%). Plastocyanin is the source of electrons for P_{700}^+ (20%).	
Question Two: electron and proton examples: NADP/NADPH+H^+; FAD/$FADH_2$; quinone/semi-quinone/quinol. Electron *only* examples: Fe•S complexes, hemes (Fe^{2+}/Fe^{3+}). (25% for each *complete* example: stoichiometry, midpoint potential).	
Question Three: Light reaction mediated thylakoidal lumen acidification and stromal alkalinization create the pmf for ATP synthesis: pmf = 2.303RT•ΔpH + F•ΔE (50%). An alkaline stromal pH will affect the Gibbs free energy ($\Delta G = \Delta G^o + 2.303RT \bullet \log_{10}$ ([ATP]/[ADP][Pi]) for ATP synthesis (increasing ΔG^o) (25%). Alkaline pH would be an effective activator of the ATP synthetase, because it is a consequence of the light reactions, just as increased reducing equivalents (which do activate the ATP synthetase) are a consequence (25%).	
Question Four: Beginning with acetyl-CoA, the hydroxypropionate pathway fixes 2 HCO_3^- molecules per cycle (with two enzymes: acetyl-CoA and propionyl-CoA carboxylases), creating a glyoxylate product and the initial substrate. The metabolic cost per C is 4 reducing equivalents (NADPH+H^+ = 2 reducing equivalents) and 1.5 ATP. It is probably insensitive to oxygen[2] (33%). The reverse Krebs cycle fixes 4 CO_2 molecules per cycle (two carboxylating steps use acetyl-CoA and succinyl-CoA as the other reactant; the two other reactions are carboxylations of PEP and alpha-ketoglutarate). The metabolic cost per C is 1.67 reducing equivalents and 0.5 ATP. It functions only in anaerobic conditions (33%). The Calvin cycle fixes one CO_2 molecule per cycle. The metabolic cost per C is 4 reducing equivalents and 3 ATP (33%).	

[1] Blankenship: pages 111 and 118.
[2] Blankenship: page 253.

Photosynthesis (SC/BIOL 4061) Final Exam (6 Dec 2006)

Answer SEVEN of the following eight questions in the exam booklet provided.

When finished, please insert the question sheet and your crib sheet(s) in the exam booklet (the crib sheet will be available to you after grading). You should be able to answer each question on one to two pages. Excessive length is not encouraged.

Question One
Explain why isotopic discrimination is evidence for the early (in geological time) appearance of photosynthesis.

Question Two
Contrast the photon energies of visible (and UV) light and the O–H bond energy of H_2O (460 kJoules mol^{-1}). Discuss the implications for oxygenic photosynthesis.

Question Three
Contrast the absorption properties of carotenoids and bilins (linear tetrapyrroles) with those of cholorphyll. Predict the peak emission wavelengths of carotenoid and bilin fluorescence. Explain why.

Question Four
Describe red light enhancement, and predict its effect on granal stacking, including the mechanism.

Question Five
Describe the activation and enzymatic mechanism of RuBisCO.

Question Six
Propose a carbon dioxide fixation and/or concentrating mechanism that would entail the lowest metabolic cost (in the form of ATP and NAD(P)H usage).

Question Seven
Describe the impact of metabolic flux outcomes (amino acids, lipid, starch, and sugar synthesis) on chloroplast stromal pH.

Question Eight
Why would overexpression of sedoheptulose 1,7 bisphosphatase result in a dramatic increase in photosynthetic productivity under normal ambient conditions?

Final Exam KEY

Question One: ^{12}C is the dominant carbon isotope (99% of total carbon compared to only a small proportion of ^{13}C [1%] and ^{14}C [negligible]). It is preferentially used by RuBisCO, probably due to its lower weight so that it is more likely to interact with the RuBisCO active site, but it may also be a steric fit in the active site. The enrichment of ^{12}C in organic material recovered from geologically old rocks is consistent with CO2 fixation and thus photosynthesis.	
Question Two: Photonic energies are lower than the energies required to 'split' the O–H bond of water (460 kJoules mol^{-1}) with the exception of UV light (471 kJoules mol^{-1}). Since the wavelength of photosynthetically active light (red, 680 nm) has a much lower energy (176 kJoules mol^{-1}), multiple photons are required to split water in oxygenic photosynthesis.	
Question Three: Carotenoids and bilins have absorption peaks between the blue and red absorption peaks of chlorophyll. To act as antenna, their emission must be lower than the red absoprtion peak of chlorophyll.	
Question Four: Red light enhancement will maxmize linear electron transport from water to NADP, resulting in lower levels of reduced PQH_2, and thus maximize granal stacking.	
Question Five: Carbamylation of a lysine at the active site is necessary for enzymatic activity of RuBisCo. At the active site, a second CO_2 interacts with carbon two of ribulose-1,5-phosphate to form a transient 6 carbon molecule, followed by cleavage.	
Question Six: Of the mechanisms we examined, carboxylation of acetyl-CoA the hydroxypropionate pathway) requires the least energy in the form of ATP and NAD(P)H, and thus would be most efficient.	
Question Seven: Of the four outcomes, amino acids will cause significant alkalinization of the chloroplast stroma because of H^+ consumption in nitrate and sulfate reduction. Lipid synthesis may have some, sugar and starch synthesis should have none.	
Question Eight: Probably variation in sucrose/starch partitioning.	