1.018/7.30J Ecology 1: The Earth System
Problem Set 1, Fall 2009

Assigned: Ses #2 **Due:** Ses #6 at the beginning of class.
Please turn in your assignments (hard copy) to the TAs.
You may work individually or in groups of up to three.

1. (11 points)
a. The following is a series of coupled electron donors and electron acceptors. Using Table 1, order this series from most energy yielding to least energy yielding. Assume that the pH for all reactions is 7.
H_2/Fe^{3+} H_2S/O_2 CH_3OH/NO_3^- H_2/O_2
Fe^{2+}/O_2 NO_2^-/Fe^{3+} H_2S/NO_3^-

b. Explain how it is possible that the same substance could be either an electron donor or an electron acceptor for different microorganisms. Under what conditions might this happen? Give one example.

c. Consider the following reaction:
$NADH + H^+ + fumarate \Rightarrow succinate + NAD^+$
Using Table 1 calculate the delta E_o' of the reaction. What is the delta $G^{o'}$? Does this reaction produce or consume energy? Does this look to you like a potential reaction in a respiratory pathway? Why or why not?

2. (11 points)
a. In the article by Des Marais, an estimate is given for global photosynthetic productivity. Using this number and the formula for photosynthesis in the Remmert paper, estimate, in kg, the annual amount of water and CO_2 consumed by photosynthesis, as well as the amount of O_2 produced.

b. The total mass of the Earth's atmosphere is approximately 5×10^{18} kg and composed of 78% Nitrogen, 21% Oxygen, and 1% Argon. In what ways was the atmosphere of the Earth 4 billion years ago different than it is today? Since there is still disagreement about Earth's early atmosphere, be sure to note sources in your answer.

c. Calculate how many years it took for the current levels of O_2 in the atmosphere to accumulate. Assume that the early atmosphere contained no O_2, photosynthesis started instantaneously at today's rate, photosynthesis was constant in time, and that respiration was negligible. Is your answer reasonable? If not, explain why.

d. Al Gore has hired you as a scientific consultant for his new movie, *More Inconvenient Truths*. While attending last Thursday's 1.018 lecture, Al heard Prof. Chisholm say that O_2 levels are declining, but not by much. Al wants to incorporate this idea into his movie, but doesn't want to use "scare tactics". Find the rate at which O_2 levels are declining (looking this number up is fine, but note sources) and explain to Al why this is occurring. Given your findings, should he include this as a detrimental effect of burning fossil fuels in his new movie? If so, why? If not, describe a mechanism by which O_2 could be reduced significantly in the atmosphere. Your idea need not be likely, just possible.

3. (11 points)
a. You have decided to follow in your TA's footsteps and pursue a career in oceanography. Because you were so inspired by 1.018, you are especially interested in the productivity of oceans due to their importance on a global scale. You break the news to a fellow classmate who says, "But don't oceans have the same productivity as deserts? How could they possibly be important on a global scale?" Explain how you are both right.

b. Your discussion about oceans and aquatic ecosystems gets you thinking about how they compare with terrestrial systems. You remember from class that five of the major environmental determinants of productivity are light, nutrients, temperature, CO_2, and H_2O. Your classmate creates the table below and asks you to fill in the factors that are most likely and least likely to limit primary production in the following ecosystems:

	Most Likely	Least Likely
Boreal Forest		
Sewage Pond		
Tropical Rainforest		
North Atlantic Ocean		

c. For each ecosystem give a one or two sentence explanation for why you chose which factors would be most likely and least likely to limit primary production. State any assumptions you make about the ecosystems while assessing the importance of each factor.

d. As you are a studious MIT student, your discussion with your classmate evolves into a conversation about the mean residence time (MRT) of carbon. Your classmate creates a table of various ecosystems and asks you to rank them in order of MRT (1-4, with 1 being the longest and 4 being the shortest). Briefly explain your methodology.

Ecosystem	Area (10^6 km^2)	NPP (g m^{-2} y^{-1})	Biomass (kg m^{-2})	Rank
Young Temperate forest	5	1300	30	
Ocean plankton	332	125	0.003	
Tropical Rain Forest	17	2200	45	
Savanna	15	900	4	

Table 1. Standard reduction potential (E_0') values (at 25°C and pH 7)

Half-Reaction			E_o' (V)
$O_2 + 2\ H^+ + 2\ e^-$	⇒	H_2O	+0.816
$Fe^{3+} + e^-$	⇒	Fe^{2+}	+0.771
$NO_3^- + 6\ H^+ + 6\ e^-$	⇒	$½\ N_2 + 3\ H_2O$	+0.75
$NO_3^- + 2\ H^+ + 2\ e^-$	⇒	$NO_2^- + H_2O$	+0.421
$NO_3^- + 10\ H^+ + 8\ e^-$	⇒	$NH_4^+ + 3\ H_2O$	+0.36
$NO_2^- + 8\ H^+ + 6\ e^-$	⇒	$NH_4^+ + 2\ H_2O$	+0.34
$CH_3OH + 2\ H^+ + 2\ e^-$	⇒	$CH_4 + H_2O$	+0.17
fumarate + $2\ H^+ + 2\ e^-$	⇒	succinate	+0.031
$2\ H^+ + 2\ e^-$	⇒	H_2 (pH 0)	+0.00
oxaloacetate + $2\ H^+ + 2\ e^-$	⇒	malate	-0.166
$CH_2O + 2\ H^+ + 2\ e^-$	⇒	CH_3OH	-0.18
pyruvate + $2\ H^+ + 2\ e^-$	⇒	lactate	-0.185
acetaldehyde + $2\ H^+ + 2\ e^-$	⇒	ethanol	-0.197
$SO_4^{2-} + 8\ H^+ + 6\ e^-$	⇒	$S + 4\ H_2O$	-0.20
$SO_4^{2-} + 10\ H^+ + 8\ e^-$	⇒	$H_2S + 4\ H_2O$	-0.21
$FAD + 2\ H^+ + 2\ e^-$	⇒	$FADH_2$	-0.219
$CO_2 + 8\ H^+ + 8\ e^-$	⇒	$CH_4 + 2\ H_2O$	-0.24
$S + 2\ H^+ + 2\ e^-$	⇒	H_2S	-0.243
$N_2 + 8\ H^+ + 6\ e^-$	⇒	$2\ NH_4^+$	-0.28
$NAD^+ + H^+ + 2\ e^-$	⇒	NADH	-0.320
$NADP^+ + H^+ + 2\ e^-$	⇒	NADPH	-0.324
$2\ H^+ + 2\ e^-$	⇒	H_2 (pH 7)	-0.414
$CO_2 + 4\ H^+ + 4\ e^-$	⇒	1/6 glucose + H_2O	-0.43
$Fe^{2+} + 2\ e^-$	⇒	Fe	-0.85

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