Ecology 1.018J/7.30 **Quiz 1** **October 2, 2008**

Please put your name on every page!

Space is provided for your answers; if you need more room, use the back of the ***same*** page.
This exam is worth 100 points, with an additional 6 points of bonus problems.
The number of points assigned to each question roughly corresponds to the amount of time you should spend answering it.

Equations that may come in handy	
$\Delta G_0' = -nF(\Delta E_0')$ $\Delta E_0' = E_0'$(oxidizing agent) - E_0'(reducing agent) $\Delta G' = \Delta G_o' + RT \ln([C]^c[D]^d/[A]^a[B]^b)$ $aA + bB \rightarrow cC + dD$	n = # e^- transferred per mole of reductant F = Faraday constant (93.67 kJ V^{-1} mol^{-1}) T = Temperature (K) R = gas constant (8.31 joules degree K^{-1} mol^{-1}) Standard state reactants: 1M, 1atm, 25°C (298°K)

*A table of standard reduction potentials may be found on the last page of the exam.

1. (11 Points) As you know, a group of organisms catalyze the oxidation of N compounds using either organic or inorganic carbon as their carbon source:

   $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$ (uses inorganic carbon)

   while others catalyze their reduction:

   $NO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2$ (uses organic carbon)

   (i) (2 Points) What are each of these processes called?

   (ii) (4 Points) What is the "metabolic classification" of organisms that carry each of these processes out? List the carbon source and the chemical species being oxidized and reduced for each of the processes.

   (iii) (5 Points) How can each group of microbes "make a living" by doing essentially opposite things? That is, how does each process benefit the organism that catalyzes it?

2. Answer the following questions "True" or "False" (1 Point Each).

______ The limiting factor for productivity in an ecosystem is always the element that is in lowest concentration.

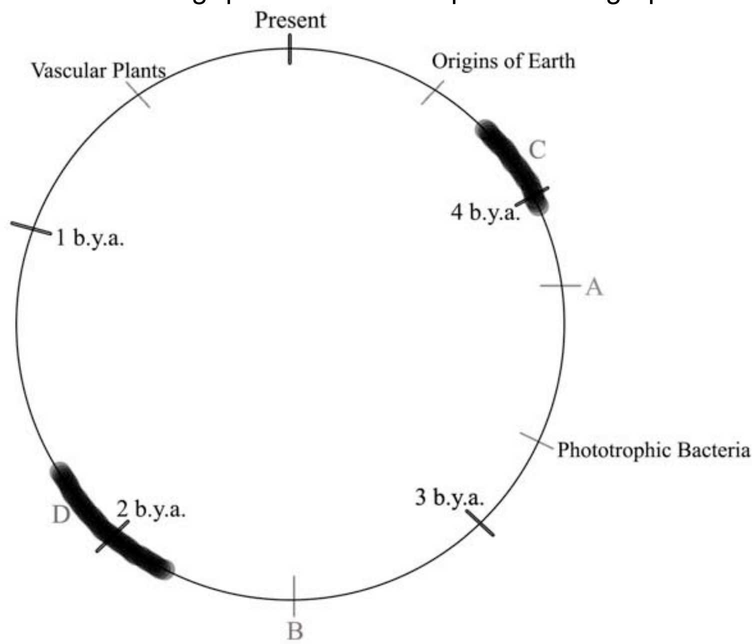
______ Net community production of an ecosystem can never be greater than net primary production.

______ N-limited lakes will often be very clear because nothing can grow in them since they are so nutrient poor.

______ Chlorophyll concentrations are maximal at the surface of the ocean where light intensity is greatest.

______ The amount of gross primary production in a forest is equal to the amount of carbon from CO_2 fixed by photosynthesis of plants and bacteria in the forest.

3. (14 Points) D. J. Des Marais diagrammed the history of the Earth as a clock in units of billions of years ago (b.y.a.) (*Science* 289: 1703(2000)). A simplified version of this clock is reproduced below. The following questions refer to parts of the graph labeled with letters.



(i) (1 Point) What appeared on Earth at "A"?

(ii) (2 Points) What atmospheric event occurred at "B"? How did it affect life at that time?

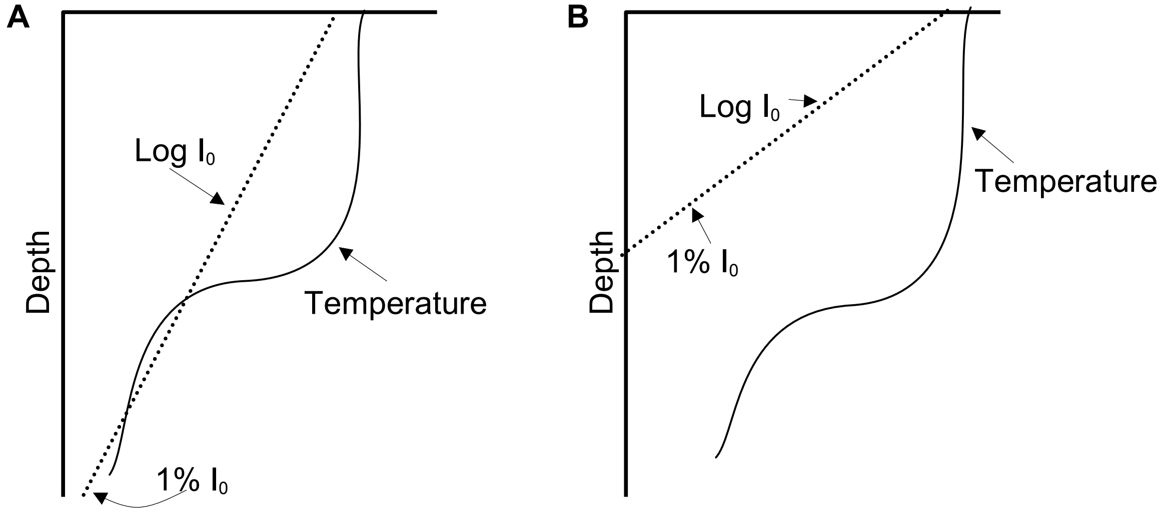
(iii) (2 Points) Describe the Earth's atmosphere at the highlighted region "C". What major gases were present?

(iv) (3 Points) Describe the Earth's atmosphere at "D". What factors led to the differences between the Earth's atmosphere between "C" and "D"?

(v) (1 Point) Draw, based on this approximate scale, when on this "clock" humans appeared on Earth.

(vi) (5 Points) Your friend, a geologist, wants your help investigating an ancient rock with curious banding and circular patterns. He has already demonstrated that the banding is not iron. What point on this graph represents the time the rock might be from? How would you test the origins of the patterning? What results would prove your hypothesis?

4. (11 Points) The graphs below describe the physical structure of two temperate lake ecosystems. I_0=incident light intensity on the water surface.



(i) (1 Point) Label z_c, the compensation depth.

(ii) (2 Points) Based on this information, which lake would you expect to produce the most phytoplankton and why?

(iii) (3 Points) Sketch on each of the graphs how you might expect the dissolved oxygen concentration to vary with depth. Why?

(iv) (5 Points) Were these profiles measured in the summer or winter? Why? How would they differ if they had been measured six months earlier? (It may help you to diagram your response.)

5. (10 Points) In your readings, Morton wrote: “All over the world, by day and night, animals and bacteria and fungi and the plants themselves are using the oxygen which photosynthesis spits out into the atmosphere to turn organic material back into carbon dioxide and water. In so doing, they regenerate the energy the plants stored away. The two processes come close to canceling each other out. Today, though, things are out of balance. Today is a spring day...”

   (i) (2 Points) Complete this thought with three sentences or more of your own to explain what is “out of balance”.

   (ii) (2 Points) What are the animals, bacteria and fungi “using the oxygen” for?

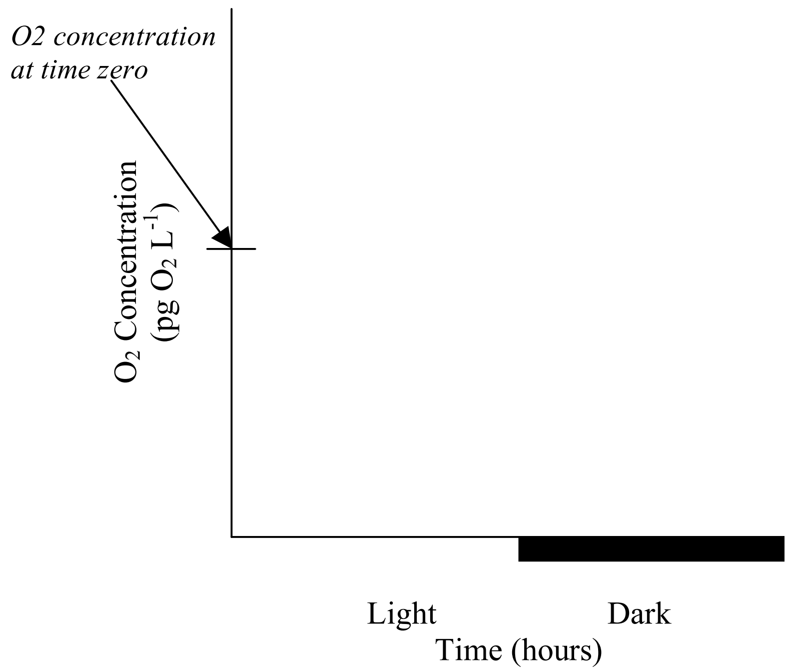
   (iii) (2 Points) If the two processes Morton describes do “cancel each other out”, can NPP still be positive? Justify your answer.

   (iv) (2 Points) Over Earth’s history, have these processes always canceled each other out? Explain your answer.

   (v) (2 Points) Morton talks about “Eating the Sun.” Explain what he means by this.

6. (17 Points) Inspired by Priestley's experiment involving a mouse, a plant, and a glass jar, you decide to build a self-sustaining closed system containing goldfish and aquatic plants.
   (i) (3 Points) What roles do the plants and fish play in your mini-ecosystem? How do they depend on one another?

   (ii) (6 Points) Before you seal off the system, you decide to do some tests to make sure your system will be balanced, i.e. the mix of fish and plants is adequate. You do this by temporarily placing the different components of your system into sealed containers and measuring the O_2 concentration for three hours in the light and three hours in darkness. On the axes below, sketch 3 graphs of the change in O_2 over time that you expect to see for the aquatic plants alone, the goldfish alone, and the aquatic plants and goldfish combined. Assume you are using sterile water.

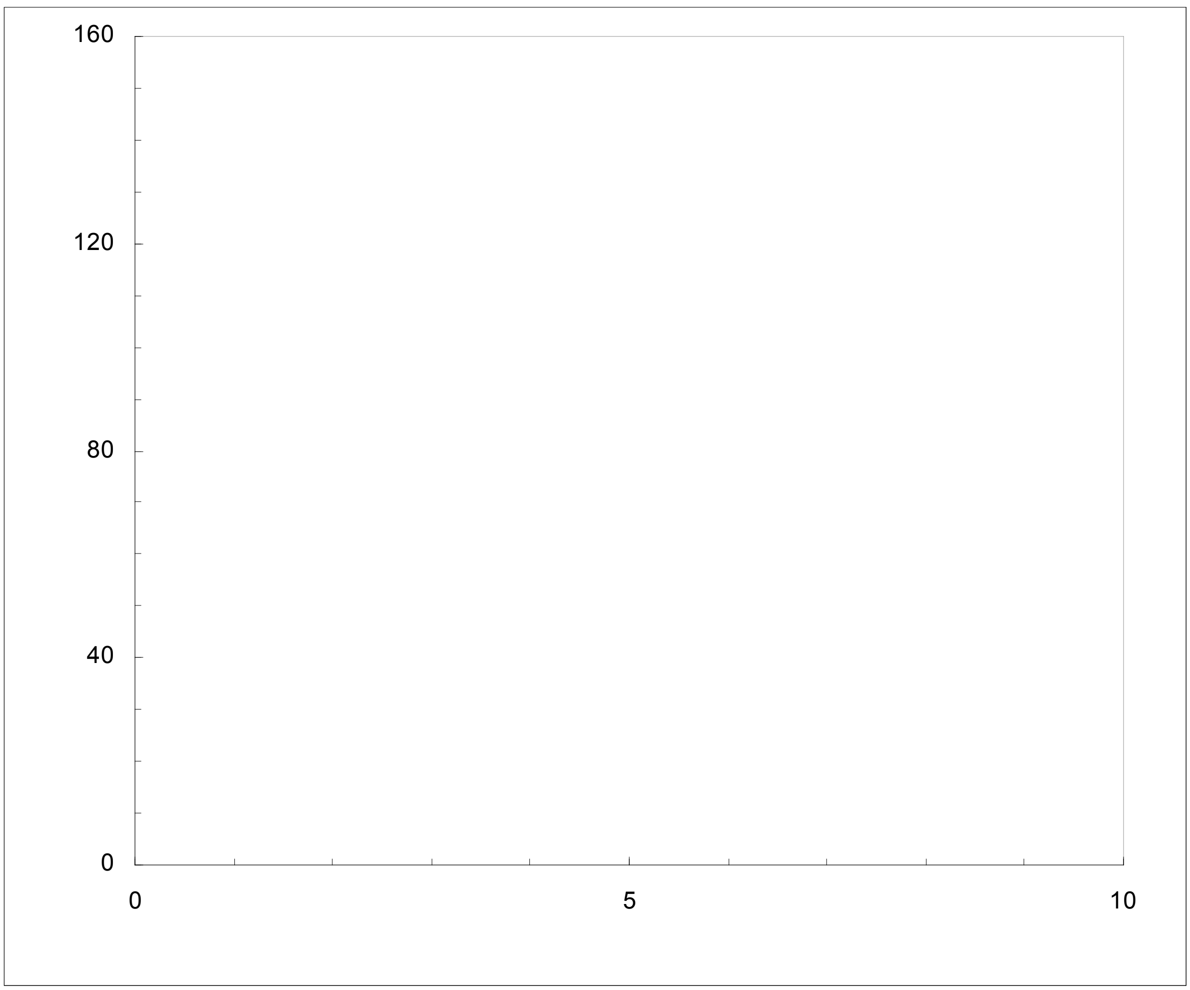


   (iii) (6 Points) Explain the features of your graphs.

   (iv) (2 Points) You decide you are ready to assemble the final system, but you are very tired from all of your problem sets and accidentally fill the container with water from the Charles River and leave it in the dark overnight. The next day, though your plant looks healthy, your fish is floating upside down. You know the water does not have anthropogenic toxins in it, because you just read a water quality report from the MDC. What do you hypothesize as the cause of death of the fish and why?

7. (16 Points) You are a limnologist studying several lakes in northern Ontario. The lakes have little input of nutrients from streams. You measure the concentrations of nitrate and phosphate every two months, and generate the following data. All units are in µg/L concentration. Using the graph paper provided below may help you answer the question.

	Trout Lake		Big Lake		Lake Balance	
	NO_3^-	PO_4^{3-}	NO_3^-	PO_4^{3-}	NO_3^-	PO_4^{3-}
January	149	8	140	10	143	9
March	113	6	113	9	128	8
May	97	5	41	4	63	4
July	37	1	5	2	31	2
September	51	2	26	3	16	1
November	133	7	83	7	92	6



(i) (6 Points) Which lake is limited by the availability of P? By the availability of N? Explain your answer.

(ii) (4 Points) In which lake do you expect more blue-green algae (cyanobacteria)? Why?

(iii) (3 Points) A resort-house development is proposed to be built around Lake Balance leading to the use of large numbers of septic systems around the lake. (Septic systems leach nitrogenous compounds into the groundwater, and the groundwater ultimately carries them to the lake). Would Lake Balance start to look more like Trout Lake or Big Lake over time?

(iv) (3 Points) The development goes ahead, and the concentrations of NO_3 in Lake Balance skyrocket. At the same time, the housing developments around the lake began to leach sewage into the lake, increasing its P supply. What might happen to the oxygen concentrations in the deep waters of Lake Balance over time and why? What is this process called?

Bonus (1 Point): Using your answer to question one, answer the following bonus question: To mitigate the effects of the added nitrate from sewage coming from the new homes surrounding Lake Balance, the local wastewater treatment authority proposes an innovative solution. Rather than trying to install a sewer system across the entire, remote area, they propose using bacteria to convert the nitrate in groundwater to nitrogen gas. They set up one of these anaerobic bacterial growth systems and test it. Initially they find that there is a high rate of conversion to N_2 gas, but these rates soon slow down. The environment is still anaerobic. What would you recommend adding to the system to help enhance the rate of conversion from NO_3^- to N_2 gas by these bacteria?

8. (8 Points) Given the following data from an Experimental Forest, answer the following questions. Show your work and units.

Total vegetative biomass	80,000 kcal m^{-2}
Detritus and organic matter in soil	120,000 kcal m^{-2}
Total Gross Primary Productivity	20,000 kcal m^{-2} yr^{-1}
Total Plant Respiration	5,000 kcal m^{-2} yr^{-1}
Total Community Respiration	9,000 kcal $m^{-2}yr^{-1}$

(i) (2 Points) What is the net primary productivity of the forest?

(ii) (2 Points) What is the net community production?

(iii) (2 Points) What is the mean residence time of carbon in the vegetative biomass?

(iv) (2 Points) Is this a fully mature forest? Explain your answer.

9. (8 Points) You are a microbe and you go to the store where they are having a sale on elemental sulfur. You are thinking about buying some elemental sulfur to consume to make energy. There's plenty of sulfur, but you need to buy something to go with it. All that's left at the store besides sulfur is nitrate (NO_3^-) and succinate. You do have the recipe (i.e. genes) to convert NO_3^- to N_2 gas and to convert S to SO_4^{2-}. You also have a recipe to convert S to H_2S and succinate to fumarate. Assume you can buy and react one mole of each in standard conditions. Should you buy the NO_3^- or the succinate if your goal is to maximize the amount of energy produced from one mole of sulfur?

Bonus Problem (up to 5 points):

The Peak District Moorlands in the United Kingdom store 20 million tonnes of carbon, almost half of the carbon stored in the soils of the entire United Kingdom (the Moorlands are only 8% of the land area). In pristine condition, these peatlands can store an additional 13,000 tonnes of carbon per year.

(i) Given this rate of productivity, how long did it take for the Peatlands to sequester this much carbon?

(ii) What is the effective residence time of the carbon that makes it into long-term storage in the peatland if no disturbance occurs? (Note: this is not a calculator problem!)

(iii) The Peak District Moorlands store carbon because they are saturated with water. Based on your knowledge of terminal electron acceptors and their efficiencies, why would this inhibit/slow respiration?

(iv) One prediction of climate change models is a reduction in rainfall in England. This would transform the Moorlands into a carbon source, emitting up to 381,000 tonnes of carbon per year. How many years would it take to respire all the carbon stored in the Peak District Moorlands? Comment on the significance of the comparison between your answer here and in Part (i).

Table 1.

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

Half-Reaction			E_o' (V)
$1/2\ O_2 + 2\ H^+ + 2\ e^-$	⇒	H_2O	+0.816
$Fe^{3+} + e^-$	⇒	Fe^{2+}	+0.771
$NO_3^- + 5\ H^+ + 6\ e^-$	⇒	$½\ N_2 + 3\ H_2O$	+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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