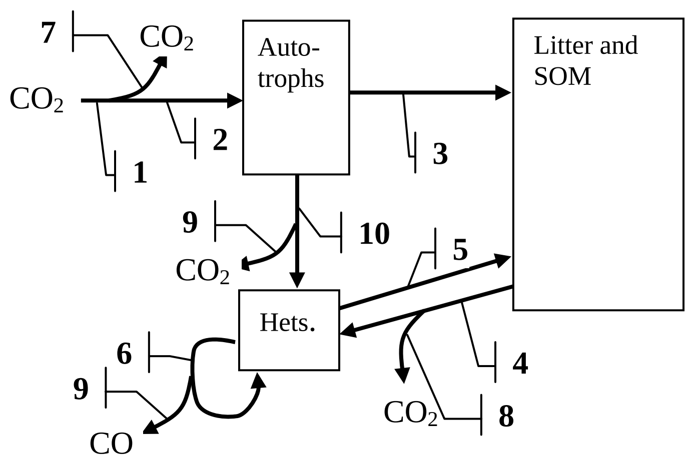
BIOL 416/516 Midterm 1 Name___KEY____________________

General Instructions. This is a closed book exam. Please turn off and put away all cell phones, iPods, and other electronic devices. Answer all of questions 1-3, then pick **either** essay 4 **or** 5 to answer. Don't miss the extra credit on the last page.

Part 1. Short answer. Answer questions 1-3. Pay attention to all components of the questions to get full credit.

1. (10 points) Below is our working diagram of the ecosystem carbon cycle, with the major pools labeled and the major fluxes indicated by arrows. First, what are the numbered fluxes? (there are 10 total, 0.5 point each; yes, there are two #9's). Second, what does this diagram tell us about the relationship between and relative magnitudes of GPP, NPP, and NEP? Why?

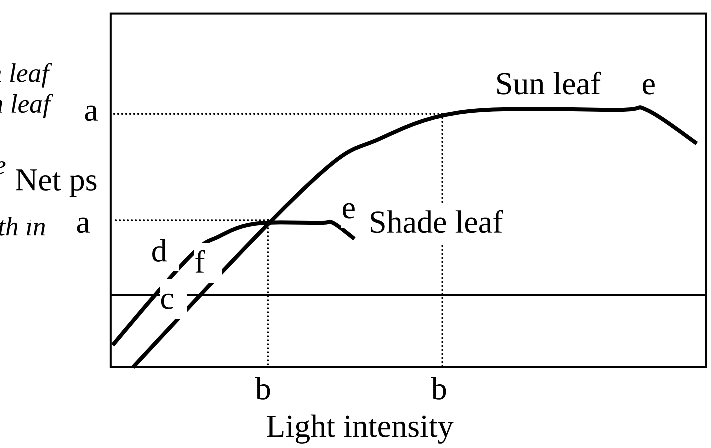


1. GPP
2. NPP
3. litterfall/senescence
4. decomposition
5. mortality/deposition by heterotrophs
6. predation/secondary consumption
7. plant respiration
8. microbial resp.
9. consumer resp.
10. herbivory/plant consumption

GPP > NPP > NEP because energy fixed by photosynthesis is lost as CO_2 by respiration at each step.

2. (12 pts) Draw a basic photosynthesis light response curve for a sun leaf. Be sure to label your axes and the six key components that describe the response of photosynthesis to light. Then add the same curve for a shade leaf, being sure to accurately portray how it differs from a sun leaf in those six key factors. Briefly state what each of those differences are.

a. max ps rate is lower for shade than sun leaf
b. saturation light intensity is lower for shade than sun leaf
c. light compensation point is lower for shade than sun leaf
d. net ps at low light is <u>*higher*</u> *for shade than sun leaf*
e. photooxidation occurs at lower light levels for shade than sun leaf
f. Quantum yield (light use efficiency) is similar for both in the range before saturation.



3. Seattle, on Puget Sound, and Spokane, in eastern Washington, are at approximately the same latitude (~47.5^o north) but differ dramatically in their climates.
a. (4 pts) First, briefly describe the global circulation patterns that set the "context" for the regional climate in the Pacific Northwest. Include consideration of where these cities are found in terms of the major atmospheric circulation cells, the source of the prevailing wind patterns, and the predominant patterns of ocean circulation.

Both cities are at mid-latitudes, putting them under the influence of the Ferrel cells in atmospheric circulation. Because of the Coriolis effect and the northward surface flow in the atmosphere with the Ferrel cell, the prevailing winds at these latitudes are from the west. Surface ocean circulation in the N. Pacific also follows a clockwise pattern. This ocean circulation brings cold water southward from the poles along the west coast of N. America, and again, because of the Coriolis effect, leads to surface waters moving westward, away from the continent. Upwelling of deep, cold, nutrient-rich ocean water helps replace this surface flow.

Note: The Ferrel cells run from roughly 30^o to 60^o latitude, so that we are roughly in the middle. Several people said that our proximity to rising air at the north boundary of the Ferrel cell is what makes this region so rainy. But part b of this question should be a good clue that that's not the case, since eastern Washington is so dry. The high ppt on the coast results from the dominant westerly winds, combined with the orographic rain effect from the Cascade Mountains.

b. (4 pts) What factors account for the <u>differences</u> in these locations in terms of average annual precipitation, temperature and seasonality?

Proximity to the oceans and topography have the biggest effect on temperature and precipitation, respectively. Proximity to the ocean affects the strength of seasonal fluctuations in temperature. Seattle's seasonal changes in temperature area moderated by the high heat capacity of water in the adjacent ocean, such that Seattle stays cooler in the summer and warmer in winter than does Spokane. Precipitation is lower in Spokane, which is on the east side of the Cascade mountains (leeward side of the prevailing westerly winds). The mountains "wring out" the moisture of incoming air masses from the oceans because of orographic precipitation, leading to a large rain shadow downwind.

Part 2. (20 pts.) Answer **one** of the essay questions, below. BE SURE TO INDICATE WHICH ONE YOU ARE ANSWERING, and be sure to address ALL components of the question to get full credit. Don't miss the extra credit question at the bottom of the last page.

4. While on vacation in Washington, D.C., you happen into George W. Bush while out for a morning jog. You trot along together and in the course of the ensuing conversation, the President lets it be known that he's not really convinced that elevated atmospheric CO_2 is being caused by humans. He thinks that it's probably just natural variation with no real reason for alarm. Here's your golden opportunity! Can you convince him otherwise based on the scientific evidence? In the process of your rebuttal, be sure to address what we know about 1) the sources of elevated CO_2 and 2) the patterns of atmospheric CO_2 over the past 50, 1000, and 650,000 years. Don't worry about trying to convince him about the <u>consequences</u> of elevated CO_2. In your description, be sure to accurately use the following key concepts: Milankovitch cycles, glacial/interglacial cycles, the deuterium temperature record, the Seuss effect (i.e., patterns of atmospheric ^{14}C), and the major global pools and fluxes of carbon, being sure to distinguish between GPP, NPP and NEP.

5. The figure below from Oberbauer et al. (2007) shows responses of tundra microcosms to warming under open-topped chambers (dark bars) compared to control plots (light bars). Explain the following: a) the relationship among the variables shown in panels A, B and C, being sure to define what each one is; b) a likely explanation for the general trend for both more negative ER and a greater response of ER to warming in the dry compared to the moist or wet ecosystems; and c) is the amount of warming in this experiment likely to be the strongest control on net gain or loss of CO_2 from tundra ecosystems? Why or why not? Include in your description what other ecosystem controls might be important determinants of net CO_2 gain or loss. Use observations from the figure to support your answer.

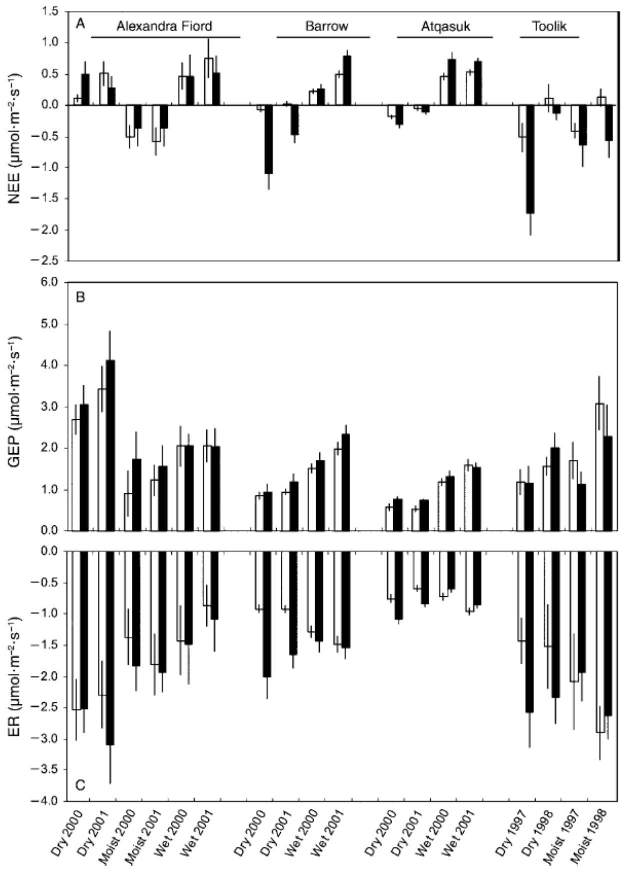


FIG. 3. (A) Net ecosystem CO_2 exchange (NEE), (B) gross ecosystem photosynthesis (GEP), and (C) ecosystem respiration (ER) for the four study locations (seasonal mean ± SE). Abscissa variables indicate ecosystem type and years of measurement. Open bars represent controls; shaded bars represent open-top chamber warming treatments. $N = 3$ for Alexandra Fiord and Toolik, and $N = 5$ for Barrow and Atqasuk. The sample size represents the number of plots measured for each treatment (warmed or control) within each ecosystem.

Q4. I list below the key points that you could have made. Given the time limitations, I was looking for 8-10 of these for full credit.

- *The long-term ice-core record shows that atmospheric CO_2 fluctuates with glacial/interglacial cycles, with high CO_2 during the warmer interglacials. The CO_2 record comes from gas bubbles trapped in the ice and the temperature record comes from the deuterium isotope record of the ice itself – with lower deuterium values (more fractionation) with colder temperatures.*
- *The current increases in atmospheric CO_2 are occurring when we were already at an interglacial high. Current CO_2 concentrations are higher than at any time in the past 650,000 years.*
- *CO_2 levels were relatively constant at ~280 ppm for the past 1000 years…*
- *until the start of the industrial revolution, when levels started to rise exponentially. As shown with atmospheric measurements, levels have continued to rise exponentially over the last 50 years and up until the present. The CO_2 records from recent (atmospheric measurements), medium term (tree ring data), and longer-term (ice core data) merge seamlessly.*
- *The glacial /interglacial cycles are thought to be entrained by Milankovitch cycles – variation in solar input resulting from variation in Earth's orbit (tilt, ,wobble, eccentricity).*
- *From the ice core record, we can't tell if increased temp leads to increased CO_2 or vice versa, but likely some type of positive feedback from the Milankovitch cycles entrains increases in CO_2 which then affects temperature.*
- *The sources of higher atmospheric CO_2 are certainly human. Evidence is both circumstantial and direct.*
- *Exponential increase in atmospheric CO_2 occurred coincident with the start of the industrial revolution.*
- *Fossil fuel releases are more than enough to account for the atmospheric increases.*
- *Humans release ~7.5 Pg C/yr through fossil fuel burning and land use conversion. 3.2 Pg C/yr remain in the atmosphere, ~2 Pg C/yr are taken up by the oceans and about 2.3 go into a northern hemisphere terrestrial sink.*
- *The ^{14}C dilutioni in the atmosphere (the Suess effect) occurs from burning fossil fuels that lack ^{14}C because they have been buried for millions of years (^{14}C half-life is only ~5700 years). The actual decrease in atmospheric ^{14}C closely follows that predicted by known emissions from fossil fuels. The Suess effect pretty much nails it on humans, Mr. President.*
- *Discrepancies between modeled and actual ^{14}C dilution indicate that about 15% of the atmospheric input comes from tropical land conversion.*
- *Measurements of ^{13}C, which is depleted in vegetation confirms this.*
- *The uptake by northern hemisphere terrestrial systems indicates that positive NEP is leading to net C storage in these systems., but we don't know how long that will last.*
- *If the sink occurs from forest regrowth or soil accumulation following succession, this may not be a permanent sink. GPP (total net photosynthesis) can decline with forest age, as can NPP (GPP – R_{plant}).*
- *If the Northern hemisphere sink stops or slows and human emissions continue to increase exponentially, then atmospheric accumulation will be much more rapid in the future.*

Q5. a. (5 pts.) NEE = net ecosystem exchange, GEP = gross ecosystem photosynthesis, ER = ecosystem respiration (this was shown in the figure legend, so just saying this was not sufficient for full credit). The crux of the question was this:
NEE = GEP - |ER|. Yes, the way we discussed it NEP = GPP – ER, but note that in this figure, ER is expressed as a negative flux. You could also say in this case that NEE = GEP + ER. Anyway, I gave credit for any of those expressions; the point wasn't to be tricky about the direction of the signs.

b. (5 pts.) Effects of the chambers on air temperature had a bigger effect on ecosystem respiration where water is not limiting soil microbial respiration and decomposition by either 1. anoxia or 2. heat capacity effects of water (preventing warming of the soil).

c. (10 pts.) Note from the question that I was looking for discussion/interpretation of the effects of temperature in <u>this experiment and related situatios</u>. In this experiment, the direct effects of warming on gross CO_2 <u>gain</u> (GEP) were minimal. Temperature had a bigger effect on CO_2 <u>loss</u> from the system (ER), however any effects were moderated by water availability in the soil, such that soil moisture had a very strong effect on net CO_2 gain or loss (NEE). The amount of warming in the soil would be moderated by the heat capacity of water in moist or wet soils and the likelihood that the energy from increased heat would be lost as latent heat rather than going into warming *the soils themselves (and the microbes in them). Increasing temperature would also have little effect if decomposition was limited by lack of oxygen (anaerobic conditions). Overall, increasing temperature had highly variable effects on NEP in the different locations and ecosystem types.*

However, temperature could have larger indirect effects on net ecosystem carbon gain via a couple of mechanisms. Increased melting of permafrost could lead to increased drainage of soil, and thereby

1. *less oxygen limitation of decomposition; and*
2. *greater response of soil temps to increased air temps.*

Extra credit (2 points). Artistically illustrate your favorite ecosystem carbon pool or flux here (points based on creativity and relevance, not how well you draw!).