Homework 4

1. **Exponential growth.** A bacteria colony with an initial population P_0 grows exponentially at a rate of 6.9% per day.

a. How many days will it take for the population to double 20 times? What will the population be after 20 doublings (i.e. how many times the original population P_0)?

b. After reaching the population level in part a, the population then crashes exponentially at a rate of 23% per day. How many days will it take for the population to decrease back to P_0?

2. **The scale of human consumption.** The photographer Chris Jordan has created extraordinary images of human consumption in which the fundamental design elements are photographs of such consumed objects as cell phones and plastic cups. In his series "Running the Numbers," the artist asserts that these images represent a certain rate of consumption or disposal, e.g. number of cell phones discarded in the U.S. per day. For the cases below, develop your own back of the envelope calculations and state whether you think the artist's estimates are reasonable:

a. "Oil barrels," representing the amount of oil consumed in the U.S. every two minutes (http://www.chrisjordan.com/gallery/rtn/#oil-barrels) U.S. primary energy consumption is about 100 quads per year. (1 quad = 1 quadrillion Btu = 10^{15} Btu = 1.055×10^{18} J = 1.055 EJ)

b. "Three Second Meditation," representing the number of items of junk mail generated and disposed of every three seconds in the U.S. (http://www.chrisjordan.com/gallery/rtn/#meditation).

c. "Tuna," representing the number of tuna fished from the world's oceans every 15 minutes (http://www.chrisjordan.com/gallery/rtn2/#tuna).

3. **Anthropogenic nitrogen fixation and its fate in the biosphere:** A total of roughly 150 Tg(N) of fixed N is added to the biosphere (mostly on land) each year because of human activity: 90 Tg(N)/y from nitrogen fertilizer application, 40 Tg(N)/y from planting of leguminous crops, and 20 Tg(N)/y from NO_x that forms in fossil fuel combustion.

a. Assuming that typical food has a C:N mass ratio of 20:1 and that the global per-capita food consumption is 2000 Cal/day,

(i) Calculate the rate of N consumption in all of the food people eat, in units of Tg(N)/y. State any other assumptions.

(ii) Express your answer also as a ratio of: (the total rate of N consumption in food/ the total rate of anthropogenic N fixation given above).

(iii) Why might this ratio be a cause for concern?

b. Suppose that 50% of the anthropogenically fixed N flows to the sea each year in runoff.

(i) What average concentration of N in river flow to the sea would that result in? Express your answer in units of moles per liter. (The world's stream flow is about 40,000 km^3/y of water flowing to the sea.

(ii) The EPA drinking water standard for nitrate in water is 10 mg(N)/liter; if all the riverine fixed nitrogen is in the form of nitrate, is the standard exceeded? What might be misleading about this estimation of a health hazard?

4. **Depleting oil stocks:** This problem requires you to look up statistics concerning petroleum resources and consumption in BP-Amoco, Statistical Review of World Energy.

http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481

a. What were proved worldwide oil reserves in 2011 (not counting oil sands)? What was world oil consumption in 2011? How long would reserves last at this rate of consumption?

b. Calculate the average annual growth rate of world oil consumption from 2001 to 2011. How long would the current reserves last if consumption grew exponentially at this rate (and no new oil is added or discovered)? (Hint: See box model solutions Case E. For more perspective on this problem, see COW, 112-113, "Exhausting Fossil Fuel Resources, II").

5. Exercise 1, COW II-3 (p. 29), "Carbon in the Biosphere." (Note: Since the answer is shown in the back of the book, you must show how you derived the answer to receive credit.)

6.

a. Exercise 2 of COW II-6 (p. 38), "A Polluted Lake." (Note: Since the answer is shown in the back of the book, you must show how you derived the answer to receive credit.)

b. Calculate the numerical values of each of the quantities in part a above (C_A, C_B, T_A, T_B) if the input values are as follows:

$V_A = 2 \times 10^8 \, L$ $\quad$ $V_B = 6 \times 10^9 \, L$

$S_A = 2 \times 10^7 \, L/y$ $\quad$ $S_B = 9 \times 10^7 \, L/y$

$E_A = 10^7 \, L/y$ $\quad$ $E_B = 5 \times 10^7 \, L/y$ $\quad$ $P = 10^3 \, g/y$

c. You are the water safety manager for the park district. When the toxic pollutant P reaches a concentration of 50 μg/L in lake water, the water is no longer safe to drink. Based on your solutions to part (b), do you need to warn campers that the water in either or both lakes is unsafe to drink?