1. (10 pts, 20 min) Your liver has been actively synthesizing proteins all morning; consequently its ATP levels are lowered and AMP/ADP levels are high. While crossing the street on your way to your favorite class, a fast moving car comes directly towards you.

   i) What hormone is released by your central nervous system, once you notice the car? (2 pts)
   ii) What will happen to the phosphorylation state of proteins due to this hormone? (2 pts)
   iii) How will the presence of this hormone affect the levels of F-2,6-P in the cell? (Will they rise or fall?) (2 pts)
   iv) Under these conditions, will the liver produce glucose from glycogen, perform gluconeogenesis or both? Briefly justify your answer with reference to how these pathways are regulated – consider both hormonal control, energy sensing, and the availability of ATP for biosynthesis. (4 pts)

2. (6 pts, 10 min) The reaction catalyzed by Malate dehydrogenase in the TCA cycle has a standard free energy change ($\Delta G^\circ$) of +29 kJ/mol, but a Gibbs free energy of 0 kJ/mol during the normal operation of the TCA cycle. Explain how the Gibbs free energy is reduced to zero for this reaction; is this accomplished by either direct or indirect coupling? (2 pts)

3. (5 pts, 5 min) A reaction that is identical in chemistry to that of pyruvate dehydrogenase occurs in the TCA cycle. Identify the name of the enzyme that catalyzes this reaction and show that the chemical changes are identical to those catalyzed by pyruvate dehydrogenase.

4. (5 pts, 5 min) Transaminases are enzymes that reversibly convert $\alpha$-keto acids to $\alpha$-amino acids by the replacement of a ketone group by an amide group, thus providing a way to both synthesize and degrade amino acids. For example, pyruvate can be converted to alanine by a transaminase, as illustrated in the reaction shown to the right. Two other amino acids can be synthesized directly from intermediates in the TCA cycle by virtue of the transaminase reaction. Draw the substrate and product of the transaminase reaction for both of these and give the name of the resultant amino acid.

5. (6 pts, 10 min) View the Jmol page for succinate dehydrogenase and answer the following questions:
   i) Is the FAD buried in the enzyme or exposed on its surface? Based on your answer, is it likely that FADH$_2$ will be released after oxidation of succinate, or remain bound to the enzyme?
   ii) Describe, or sketch, the electron transfer path from succinate to coenzyme Q. What happens to the electrons received from succinate on the way to coenzyme Q?

6. (5 pts, 10 min) The diagram to the right shows actual data for the recovery of muscle glycogen after exercise for an individual on either high-carbohydrate diet (solid line) or for an individual on a diet that consists of fat and protein (dashed line). The recovery period starts at T=0 after an exercise period of 2 hours (from T = -2 to 0 hours). Explain, using your knowledge of the metabolic pathways discussed in this course, the reason for the slow (almost non-existent) recovery of muscle glycogen for the individual on the fat and protein diet.

7. (5 pts, 5 min) Lactic acid has a number of industrial uses, including the manufacture of plastics, and can be produced in bacteria using similar metabolic pathways as in other organisms we have studied. If you wanted to have bacteria produce large amounts of lactic acid from glucose, which enzyme in their metabolic pathway would you inactivate?

8. (8 pts, 10 min) Ethanol can be produced from glucose by yeast (and other organisms), a process referred to as fermentation. Glucose can be readily obtained from sugar cane syrup (which occurs in Brazil), and with more expense, from corn starch (as is done in the United States).
   i) If you wanted to maximize the production of ethanol – would you grow the yeast cells in the presence of a high concentration of oxygen or low? Why? (2 pts)
ii) How efficient is the process of ethanol production, i.e. how much of the original energy content in glucose is retained in the ethanol? You can estimate the energy remaining in ethanol by first determining how many ATP molecules can be produced from one glucose molecule, and then subtract the net number of ATPs that were generated going from glucose to pyruvate (6 pts).

9. (5 pts, 10 min) The concentration of chloride in seawater is 0.6 M. An ocean dwelling bacteria uses chloride transport to generate ATP. What is the minimum number of chloride ions that would have to be moved through its ATP synthase to generate ATP? You can assume the intracellular concentration of chloride is 0.1 M and that the voltage difference across its membrane is 0.06 V, inside positive, and the temperature is 300K.