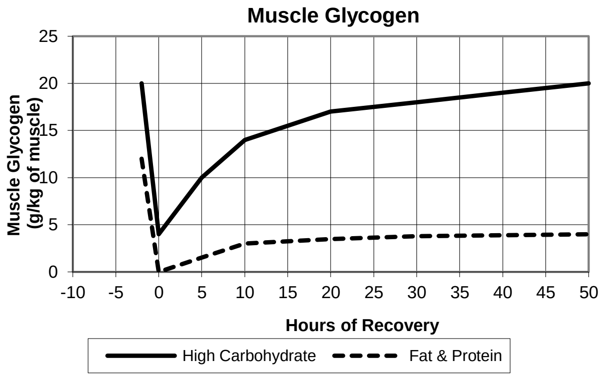
1. (10 pts, 15 min) Your liver has been actively synthesizing proteins all morning; consequently, its ATP levels are lowered and AMP/ADP levels are high. While crossing the street on your way to your favorite class, a fast moving car comes directly towards you.
   i) What hormone is released by your central nervous system, once you notice the car? (2 pts)
   ii) What will happen to the phosphorylation state of proteins due to release of this hormone? (2pts)
   iii) How will the presence of this hormone affect the levels of F2,6-P in the cell? (Will it 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. (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.



3. (5 pts, 10 min) Summarize the various roles of histidine in the mechanism of serine proteases, citrate synthase, and succinate thiokinase.

4. (6 pts, 20 min) The reaction catalyzed by Malate dehydrogenase in the TCA cycle has a standard free energy change (ΔG^o) of +29 kJ/mol, but a Gibbs free energy of ~0 kJ/mol during the normal operation of the TCA cycle.
   a) Given that the concentration of malate, NAD^+, and NADH are 100 μM in the cell, calculate the concentration of oxaloacetate during the normal operation of the TCA cycle (4 pts). Assume T=300K. For the reaction A+B→C+D: $\Delta G = \Delta G^0 + RTln[C][D]/[A][B]$
   b) Explain how the Gibbs free energy is reduced to zero for this reaction; is this accomplished by either direct or indirect coupling? (2 pts)

5. (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.

6. (10 pts, 10 min) The concentration of chloride in seawater is 0.6 M. An ocean-dwelling bacterium 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.

7. (4 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?

8. (6 pts, 10 min) Ethanol can be produced from glucose by yeast (and other organisms) under conditions of low oxygen, a process referred to as fermentation. How efficient is the process of ethanol production, i.e. how much of the original energy content in glucose is retained in the ethanol? Hint. Compare the energy released going from glucose to CO_2 versus the energy released going from ethanol to CO_2, assuming that the pathway to ethanol is reversible.