1. **Cyclic AMP** and **AMP** can both stimulate the breakdown of glycogen in muscle, but they act by different mechanisms, and they represent different signals calling for glycogen degradation. Explain the conditions producing each of these compounds, and how each acts to stimulate glycogen phosphorylase.

2. **Cyclic AMP** in liver is produced upon hormonal stimulation by glucagon. In addition to affecting glycogen breakdown, as in muscle, gluconeogenesis from pyruvate is stimulated and glycolysis is inhibited. Explain the series of reactions by which this regulation is accomplished, including the phosphorylation state and activity of all intermediates in the process.
Biosynthetic (anabolic) pathways convert low energy precursors into products with higher standard free energies. For the overall process to be spontaneous, additional energy must be supplied in some form, often by coupling to hydrolysis of ATP or some other nucleoside triphosphate. For the following biosynthetic pathways, identify the steps requiring ATP (or its equivalent GTP or UTP), and for each step give the reactants, products (name or structure), and name of the enzyme.

(a) Conversion of pyruvate to glycogen. (four steps required)

(b) Synthesis of triose phosphate from CO₂ in the Calvin-Benson cycle of photosynthesis.
(15) 4. A number of components are involved in mitochondrial electron transport and oxidative phosphorylation. Match a component or components in the list at the right with each statement below by placing the appropriate letter or letters in the blank to the left of the statement. (More than one component may fit a statement).

_____ a peripheral membrane protein, easily detached from the membrane.  
   a. F₁ complex
   b. F₀ complex

_____ has ATPase activity
   b. coenzyme Q

_____ contains cytochrome c₁
   b. coenzyme Q

_____ lipid soluble electron carrier
   c. complex I

_____ contains Cu
   d. complex II

_____ acts as a proton pump
   e. complex III

_____ contains a flavoprotein
   f. complex IV

_____ oxidizes NADH
   g. cytochrome c

_____ reduces oxygen

_____ reduces coenzyme Q

(15) 5. A number of components are involved in the light reaction of plant photosynthesis. Match a component in the list at the right with each statement below by placing the appropriate letter in the blank. Only one component per blank. (P700 is pigment system I, P680 is pigment system II).

_____ reduced directly by P₆₈₀⁺
   a. Z, a tyrosine residue

_____ reduced directly by P₇₀₀⁺
   b. phycocyanin

_____ oxidized directly by P₆₈₀⁺
   c. plastocyanin

_____ oxidized directly by P₇₀₀⁺
   d. Ao, a chlorophyll molecule

_____ an accessory pigment
   e. pheophytin

_____ chlorophyll a without Mg²⁺
   f. cytochrome a₃

_____ reduced by cytochrome b/f complex
   g. ferredoxin

_____ removes electrons from the Mn cluster

_____ a Cu containing protein

_____ an Fe/S protein
(6) 6. The enzyme transketolase plays an important role in the dark reaction of photosynthesis. Give a reaction catalyzed by this enzyme, including the structure of both reactants and products.

(9) 7. Rubisco is the most abundant protein in the biosphere. What is the full name of this enzyme?

It reacts with both CO₂ and with O₂. Identify both reactions by giving the structure of the reactants and products.

(15) 8. Diagram the thylakoid membrane, identifying the space on each side of it. On your diagram, place, in proper orientation, the following:

CF₁, CF₀, plastocyanin, pigment system I, pigment system II, cytochrome b/f complex, site of O₂ production, site of NADPH production, Rubisco, ferredoxin