

Points

1. Following is the overall reaction catalyzed by the Calvin-Benson cycle:



Give the **structures** of reactants and products for the **step** or **steps** of the cycle which:

(4) (a) Incorporates CO₂ into an organic form (one reaction).

(8) (b) Use ATP as a substrate (two reactions).

(4) (c) Uses NADPH as a substrate (one reaction).

(6) 2. An alternative fixation of CO₂ into organic form occurs in tropical grasses which are called **C-4 plants**. This alternative C-4 “pathway” is called the Hatch-Slack pathway. Give the **structures** of the reactants and products for this reaction of CO₂, and **explain what function this pathway serves**.

Page	Points
1	_____
2	_____
3	_____
4	_____
5	_____
Total	_____

3. Pyruvate kinase has a very large negative ΔG° , and so the reaction operates with a large negative ΔG and is essentially irreversible.
- (8) (a) How do animal cells carry out the conversion of pyruvate to phosphoenol pyruvate? Give the reactants, products, (**names or structures**) and the name(s) of the enzyme(s) involved.
- (4) (b) How do C-4 plant cells carry out this conversion? Give the reactants, products, (**names or structures**) and the name(s) of the enzyme(s) involved.
- (10) 4. One of the key reactions of both the Calvin-Benson cycle and the phosphogluconate pathway is catalyzed by the enzyme **transketolase**.
- (a) Give the **structure** and **name** of the products formed when this enzyme catalyzes the reaction between fructose-6-phosphate and glyceraldehyde-3-phosphate.
- (b) What prosthetic group is found on transketolase?

- (10) 5. Stimulation of liver by the hormone **glucagon** results in several metabolic changes that lead to the increase in glucose synthesis and excretion by liver. One of these changes involves inhibition of glycolysis and stimulation of gluconeogenesis (i.e. the conversion of phosphoenolpyruvate to glucose). Describe all the steps and intermediates involved in this stimulation, beginning with the hormone interacting with its cellular receptor, and ending with the glycolytic/gluconeogenic enzymes that are affected.
- (6) 6. Metabolic compartmentation plays an important role in metabolic regulation because not all intermediates can cross intracellular membranes. For example, fatty acids are activated in the cytoplasm to the CoASH esters, but must enter the mitochondrial matrix in order for oxidation to occur. Explain how fatty acyl-CoA esters are transported across the inner mitochondrial membrane.

7. As a way of comparing the energy available from the oxidation of fatty acids to that available from the oxidation of carbohydrates, one could compare the ATP produced from the oxidation of a six carbon fatty acid (hexanoic acid: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$) with that produced from a six carbon sugar (glucose). Following is a summary of the ATP calculation for glucose, assuming 2.5 ATP per mitochondrial NADH and 1.5 ATP per cytoplasmic NADH and mitochondrial CoQH_2 .

hexokinase and PFK-1		-2 ATP
glyceraldehyde-3-P dehydrogenase	2 cytoplasmic NADH	$2 \times 1.5 = 3$ ATP
3-phosphoglycerokinase		2 ATP
pyruvate kinase		2 ATP
Pyruvate dehydrogenase	2 mitochondrial NADH	$2 \times 2.5 = 5$ ATP
2 acetyl-CoA in TCA cycle	3 x 2 NADH 2 CoQH_2 2 GTP	$6 \times 2.5 = 15$ ATP $2 \times 1.5 = 3$ ATP equiv. to: 2 ATP
	Total net per glucose:	30 ATP

- (14) (a) Sketch the pathway, including structures of all intermediates derived from hexanoic acid, for the degradation of hexanoic acid to acetyl-CoA in the mitochondrial matrix, showing utilization or production of coenzyme cosubstrates ATP, GTP, CoQH_2 and NADH. Assume that hexanoic acid is activated in the mitochondrial matrix in the same way as acetoacetate, not in the cytoplasm as longer chain fatty acids are activated.
- (6) (b) Summarize the overall ATP production for complete oxidation of hexanoic acid in a manner similar to that done for glucose above. There is no need to give the detailed steps for breakdown of acetyl-CoA by the TCA cycle, but show the calculation of ATP's for that process.

For questions 8-17, check the blank corresponding to the **best** answer. (2 pts each question)

8. Which of the following is **not** a ketone body:
- _____ acetoacetate
 - _____ beta-hydroxy butyrate
 - _____ oxaloacetate
 - _____ acetone
9. Muscle is unable to synthesize glucose because it lacks the enzyme:
- _____ phosphorylase
 - _____ hexokinase
 - _____ glucose-6-phosphatase
 - _____ F-1,6-BPase
 - _____ pyruvate kinase
10. The enzyme interconverting ribose-5-phosphate and ribulose-5-phosphate is:
- _____ triose phosphate isomerase
 - _____ pentose phosphate isomerase
 - _____ hexose phosphate isomerase
 - _____ pentose phosphate epimerase
 - _____ pentose phosphate kinase
 - _____ pentose phosphate carboxylase
11. The enzyme interconverting xylulose-5-phosphate and ribulose-5-phosphate is:
- _____ triose phosphate isomerase
 - _____ pentose phosphate isomerase
 - _____ hexose phosphate isomerase
 - _____ pentose phosphate epimerase
 - _____ pentose phosphate kinase
 - _____ pentose phosphate carboxylase
12. Chylomicrons carry triglycerides made from _____ which are hydrolyzed in the blood by the enzyme _____.
- _____ dietary fat; pancreatic lipase
 - _____ adipose tissue fat, lipoprotein lipase
 - _____ biosynthetic fat, hormone sensitive lipase
 - _____ dietary fat, lipoprotein lipase
 - _____ adipose tissue fat, hormone sensitive lipase
 - _____ biosynthetic fat, pancreatic lipase
13. Which enzyme is found in the phosphogluconate pathway, but not in the Calvin-Benson cycle?
- _____ transketolase
 - _____ aldolase
 - _____ transaldolase
 - _____ pentose phosphate isomerase
 - _____ ribulose bis phosphate carboxylase
14. Which enzyme does not produce NADPH as a product?
- _____ malate dehydrogenase
 - _____ malic enzyme
 - _____ glucose-6-phosphate dehydrogenase
 - _____ 6-phosphogluconate dehydrogenase
15. Liver cannot degrade acetoacetate because it lacks the enzyme
- _____ thiolase
 - _____ carnitine acyl transferase
 - _____ beta-ketoacyl CoA transferase
 - _____ thiokinase
 - _____ citrate synthase
16. Odd chain fatty acids are degraded to propionyl-CoA. The first step in its degradation is conversion to _____ by the enzyme _____.
- _____ succinyl-CoA; methylmalonyl-CoA mutase
 - _____ methylmalonyl-CoA; propionyl-CoA carboxylase
 - _____ hydroxymethylglutaryl-CoA; HMG-CoA synthase
 - _____ acetyl-CoA; propionyl-CoA decarboxylase
17. In the Cori cycle, _____ circulates from the liver to the muscle, and _____ circulates from the muscle to the liver.
- _____ acetoacetate; lactate
 - _____ lactate; glucose
 - _____ pyruvate; glucose
 - _____ glucose; acetoacetate
 - _____ glucose; lactate
 - _____ glucose; pyruvate