1. The Citric Acid Cycle (CAC) enzyme that has a mechanism similar to pyruvate dehydrogenase (and requires TPP, lipoic acid, FAD) is:
   a. malate dehydrogenase.  b. succinate dehydrogenase.  c. alpha-ketoglutarate dehydrogenase.  
   d. isocitrate dehydrogenase.  e. fumarase.

2. Consider the glycolytic enzyme enolase, the CAC enzyme that in principle works in reverse of enolase (when the CAC cycle is moving forward) is:
   a. citrate synthase.  b. aconitase.  c. isocitrate dehydrogenase.  d. fumarase.  e. hexokinase.

3. Suppose a mitochondrial preparation was given ONE pyruvate that was $^{14}$C-labeled in the carbonyl carbon. The second round of the CAC would liberate _____% of the label as CO$_2$.
   a. 25%.  b. 50%.  c. 75%.  d. 100%.  e. 0%.

4. Suppose a mitochondrial preparation was given ONE pyruvate that was $^{14}$C-labeled of the carboxyl carbon. The second round of the CAC cycle would liberate _____% of the label as CO$_2$.
   a. 25%.  b. 50%.  c. 75%.  d. 100%.  e. 0%.

5. When pyruvate is converted to glucose (gluconeogenesis), it is first converted to PEP by an enzyme system which must first:
   a. oxidize ATP.  b. fix CO$_2$.  c. reduce NAD$^+$.  d. oxidize NAD$^+$.  e. remove C=O.

6. In glycogen utilization, debranching enzyme is an alpha 1,6 hydrolase AND a:
   a. phosphorylase.  b. transglycosidase.  c. dehydrogenase.  d. glycosidase.  e. oxidase.

7. The major immediate product of glycogen breakdown is:
   a. glucose-6-phosphate.  b. glucose-4-phosphate.  c. glucose-2-phosphate.  
   d. glucose-1-phosphate.  e. glucose.

8. Phosphorylase kinase phosphorylates glycogen synthase make it:
   a. active.  b. inactive.  c. neutral.  d. allosterically inhibited by ATP.  e. dissolve in water.

9. Which of the following is not true of the reaction catalyzed by the pyruvate dehydrogenase complex?
   a. Biotin participates in the decarboxylation.  b. Both NAD$^+$ and a flavin nucleotide act as electron carriers.  
   c. The reaction occurs in the mitochondrial matrix.  d. The substrate is held by the lipoyl-lysine “swinging arm.”  
   e. Two different cofactors containing —SH groups participate.

10. Glucose labeled with $^{14}$C in C-3 and C-4 is completely converted to acetyl-CoA via glycolysis and the pyruvate dehydrogenase complex. What percentage of the acetyl-CoA molecules formed will be labeled with $^{14}$C, and in which position of the acetyl moiety will the $^{14}$C label be found?
    a. 100% of the acetyl-CoA will be labeled at C-1 (carboxyl).  b. 100% of the acetyl-CoA will be labeled at C-2.  
    c. 50% of the acetyl-CoA will be labeled, all at C-2 (methyl).  d. No label will be found in the acetyl-CoA.  
    e. Not enough information is given to answer this question.

11. Malonate is a competitive inhibitor of succinate dehydrogenase. If malonate is added to a mitochondrial preparation that is oxidizing pyruvate as a substrate, which of the following compounds would you expect to decrease in concentration?

12. Acetyl-CoA is not glucogenic in humans because humans lack:
13. The conversion of 1 pyruvate to 3 CO₂ in the mitochondrion produces ____ NADH: ____ FADH₂: ____ GTP.

14. Anaplerotic reactions feed the citric acid cycle by making:
   a. citrate.  b. succinate.  c. oxaloacetate.  d. acetyl-S-CoA.  e. malate.

15. Anaplerotic reactions are required because citric acid cycle intermediates are used for the synthesis of:
   a. amino acids.  b. propyrins.  c. glucose.  d. all of the above.  e. none of the above.

16. The correct order of enzymes of β-oxidation is:
   1. hydroxyacyl-S-CoA dehydrogenase.
   2. thiolase.
   3. enoyl-S-CoA hydratase.
   4. acyl-CoA dehydrogenase.
   a. 1,2,3,4.  b. 4,1,3,2.  c. 4,3,1,2.  d. 1,4,3,2.  e. 4,2,3,1.

17. Activation of fatty acid in the cytoplasm for β-oxidation requires energy which is equivalent to:
   a. 1 ATP.  b. 2 ATPs.  c. 3 ATPs.  d. 4 ATPs.  e. 1 NADH.

18. Ketone bodies are formed in the liver and transported to extra-hepatic tissues as:
   a. acetoacetyl-S-CoA.  b. acetone.  c. β-hydroxybutyric acid.  d. lactic acid.
   e. β-hydroxybutyryl-S-CoA.

19. Lipoprotein lipase acts in:
   a. hydrolysis of triacylglycerols of plasma lipoproteins to supply fatty acids to various tissues.
   b. intestinal uptake of dietary fat.  c. intracellular lipid breakdown of lipoproteins.
   d. lipoprotein breakdown to supply needed amino acids.  e. none of the above.

20. Free fatty acids in the bloodstream are:
   a. bound to hemoglobin.  b. carried by the protein serum albumin.
   c. freely soluble in the aqueous phase of the blood.  d. nonexistent; the blood does not contain free fatty acids.
   e. present at levels that are independent of epinephrine.

21. Transport of fatty acids from the cytoplasm to the mitochondrial matrix requires:
   a. ATP, carnitine, and coenzyme A.  b. ATP, carnitine, and pyruvate dehydrogenase.
   c. ATP, coenzyme A, and hexokinase.  d. ATP, coenzyme A, and pyruvate dehydrogenase.
   e. carnitine, coenzyme A, and hexokinase.

22. Which compound below is an intermediate of β oxidation:
   a. CH₃(CH₂)₂₀-CO-COOH.  b. CH₃-CH₂-CO-CH₂-COOP-O-.  c. CH₃-CH₂-CO-CH₂OH
   d. CH₃-CH₂-CO-CO-S-CoA.  e. CH₃-CH₂-CO-CH₂-CO-S-CoA.

23. Which of the following is a zymogen that can be converted to an endopeptidase that hydrolyzes peptide bonds adjacent to Lys and Arg residues?

24. Which of these directly donates a nitrogen atom for the formation of urea during the urea cycle?

25. Conversion of ornithine to citrulline is a step in the synthesis of:
   a. aspartate.  b. carnitine.  c. pyruvate.  d. tyrosine.  e. urea.

26. Which of the following statements is false in reference to the mammalian synthesis of urea?
   a. Krebs was a major contributor to the elucidation of the pathway involved.
b. The amino acid arginine is the immediate precursor to urea.
c. The carbon atom of urea is derived from mitochondrial $\text{HCO}_3^-$
d. The precursor to one of the nitrogens of urea is aspartate.
e. The process of urea production is an energy-yielding series of reactions.

27. The human genetic disease phenylketonuria (PKU) can result from:
a. deficiency of protein in the diet.  
b. inability to catabolize ketone bodies.  
c. inability to convert phenylalanine to tyrosine.  
d. inability to synthesize phenylalanine.  
e. production of enzymes containing no phenylalanine.

28. Which substance is not involved in the production of urea from $\text{NH}_4^+$ via the urea cycle?
a. Aspartate.  
b. ATP.  
c. Carbamoyl phosphate.  
d. Malate.  
e. Ornithine.

29. Amino acid catabolism takes place in the:
a. nucleus.  
b. microsomes.  
c. endoplasmic reticulum.  
d. cytoplasm.  
e. mitochondria.

30. Urea synthesis in mammals takes place primarily in tissues of the:
a. brain.  
b. kidney.  
c. liver.  
d. skeletal muscle.  
e. all of these.

Written Answer Questions

1. For the average adult (70 kg or 154 lb), 15% of the body is fat.
   a. Calculate the energy reserve in terms of kJ. Assume 38 kJ/gram fat. (5 points)
   b. Our 70 kg human consumes roughly 8,400 kJ/day (which is 2,000 kcal/day or 2,000 dietary cal/day).
   Clicker Question: How long could this person survive on their fat reserves? (5 points).

2. A new manufacturer of IV saline+glucose solutions got into trouble for mixing up the proportions of saline (normally 0.9% as NaCl) and glucose (normally 5%). What was the actual glucose concentration in mM of this unfortunate IV product? The molecular weight of glucose is 180 Daltons. (10 points).
3. The malate dehydrogenase reaction has a $\Delta G^{\circ}$ of 29 kJ/mole. In most mitochondrial preparations the ratio of $[\text{NAD}^+]/[\text{NADH}]$ is 10 and the [malate] is 0.2 mM. Calculate the concentration of oxaloacetate. (10 points).