Medical Biochemistry Examination II
November 10, 2001
Kresge Auditorium
Please follow these directions:

1. Do not begin the exam until all students have received a copy of the exam. You will be instructed as to when to break the seal.

2. The exam consists of 86 questions on 17 pages, with this title page considered page 1. There are 150 points on this exam. The point value for each question is indicated by the question. For multiple answer questions without a defined number of answers 0.25 points will be deducted for each incorrect answer, although the lowest point value assigned for a question is 0. **No multiple answer question will have more than 4 correct answers.** If a question has a defined number of answers, there is no penalty for guessing.

3. Place your ID number on every page of the exam booklet and on the answer sheet you will hand in. Also, print your name on the line provided on the answer sheet.

4. There is one answer sheet for this exam. Fill in the circle for the correct answer(s) completely. If you believe that a question has more than one correct answer fill in all answers for that question completely. If you wish to change an answer, be sure to erase cleanly. **Make sure that you use your biochemistry ID number to fill in the ID box. You should use the three leftmost boxes to insert your number.**

5. When you are finished with the exam, return both the test booklet and the answer sheet. The test booklet will be returned to you when the grading is complete. **Be sure to pick up the next section of the course syllabus as you leave.**

6. Questions will not be allowed during the exam. If you believe there is a typographical error do the best you can with the information available. Do not spend extra time on the question. If it is determined that the information presented is ambiguous, or in error, then the question will not be counted in the final scoring.

7. Following the last page of the exam are two blank pages for your use, and a third page which can be used by you to list your answers. You can take this sheet with you from the exam, and use it to check your answers against the posted answers (outside of room 3109 MSB). **You will not be given extra time to fill out this answer sheet.** Answers will be posted on November 14th, at 2:00 pm, assuming that all students attend the exam at its scheduled time.

8. You will have **3.5 hours (until 12:00 pm)** to complete this exam. Good luck.
1. (1 point) Which of the following carbohydrates contain α (1,4) linkages? This question may have more than one correct answer. Indicate all correct answers on the answer sheet.

A. Glycogen  
B. Isomaltose  
C. Lactate  
D. Maltose  
E. Sucrose  
F. Trehalose

2. (1 point) The tissue which contains the highest concentration of glycogen is which ONE of the following?

A. Adipocyte  
B. Brain  
C. Liver  
D. Lung  
E. Muscle

3. (1 point) Consider the conversion of propionyl-CoA to carbon dioxide and water (ie, complete oxidation). Which of the following vitamins would NOT be required for this to occur? This question may have more than one correct answer; indicate all correct answers on the answer sheet.

A. Biotin  
B. Niacin  
C. Phosphopantetheinic acid  
D. Riboflavin  
E. Thiamine  
F. Vitamin B6  
G. Vitamin B12

4. (1 point) The synthesis of glycogen by glycogen synthase requires which TWO of the following substrates?

A. A glycogen primer  
B. Glucose-1-phosphate  
C. Glucose-6-phosphate  
D. Maltose  
E. UDP-galactose  
F. UDP-glucose
Questions 5-10 (2 points each) are based on the following situation. Consider a sprinter running a 200 meter race, who is at the 100 meter mark. Indicate the activity and phosphorylation state of the following enzymes by choosing an answer from choices A through D. There is only **ONE** answer per question, and an answer may be used once, more than once, or not at all.

5. Muscle glycogen phosphorylase
6. Muscle PFK-1
7. Muscle pyruvate kinase
8. Muscle glycogen synthase
9. Muscle protein phosphatase I
10. Muscle phosphorylase kinase

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11. (1 point) A form of type II diabetes known as MODY is due to a defect in which **ONE** of the following pancreatic enzymes?

   A. Glucokinase
   B. GLUT 4
   C. Glycogen phosphorylase
   D. Insulin receptor
   E. Phosphofructokinase-1
   F. Protein inhibitor I

12. (2 points) Consider the conversion of the carbons from muscle derived lactate to liver glycogen. Which of the following liver enzymes are **NOT** required for this conversion to occur? This question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet.

   A. Glyceraldehyde-3-phosphate dehydrogenase
   B. Glycogen phosphorylase
   C. Glycogen synthase
   D. Lactate dehydrogenase
   E. Malate dehydrogenase
   F. Phosphoglucomutase
   G. Phosphoglyceromutase
   H. Pyruvate dehydrogenase
   I. Succinate dehydrogenase
13. (1 point) A lack of the enzyme ETF:CoQ oxidoreductase leads to death. This is due to which ONE of the following reasons?

A. The energy yield from glucose utilization is dramatically reduced
B. The energy yield from alcohol utilization is dramatically reduced
C. The energy yield from ketone body utilization is dramatically reduced
D. The energy yield from fatty acid utilization is dramatically reduced
E. The energy yield from glycogen utilization is dramatically reduced
F. None of the above

Questions 14-17 (2 points each) compare the two main energy stores glycogen and triacylglycerol. If the questions refers to glycogen, answer A should be selected. If the statement refers to triacylglycerol, then answer B should be selected. If the statement refers to both energy stores, answer C should be selected, and if the statement refers to neither energy store, answer D should be selected. Each question has only ONE answer, and an answer may be used once, more than once, or not at all.

14. Synthesized in the cytoplasm
A. Glycogen only

15. Synthesis inhibited by phosphorylation of key enzymes
B. Triacylglycerol only
C. Both glycogen and triacylglycerol

16. Degradation inhibited by epinephrine
D. Neither glycogen or triacylglycerol

17. Stored in specialized cells

18. (1 point) Hypoglycemia can result from the following enzyme deficiencies or treatments EXCEPT for which one(s)? This question may have more than one correct answer; indicate all correct answers on the answer sheet.

A. Insulin receptor
B. IV fructose infusion
C. IV glucose infusion
D. Glucose-6-phosphatase
E. Glucose-6-phosphate dehydrogenase
F. Glycogen phosphorylase (liver)
G. Medium chain acyl-CoA dehydrogenase
19. (1 point) The ATP yield from the complete oxidation of one mole of a C₁₉₀ fatty acid to carbon dioxide and water would be closest to which ONE of the following?

A. 104.5  
B. 114.5  
C. 124.5  
D. 134.5  
E. 144.5

20. (1 point) Which of the following fatty acids can be synthesized by humans? This question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet.

A. Cis Δ 9, 12, 15 C₁₈₃  
B. Cis Δ 9, 12 C₁₈₂  
C. Cis Δ 9, 12, 15 C₂₁₃  
D. Cis Δ 9, 11 C₂₀₂  
E. Cis Δ 6, 9 C₁₈₂  
F. Cis Δ 6, 9, 12 C₁₈₃
Questions 21-26 (2 points each) are based on the following lists. The questions indicate a list of hereditary metabolic defects involving loss of function of single enzymes of carbohydrate metabolism, and the answers consist of possible consequences of such defects. Match each enzyme defect with its **ONE** most likely consequence. An answer may be used once, more than once, or not at all.

21. Lack of glucose-6-phosphatase  
   A. Inability to make glycogen from any sugar or to utilize galactose as an energy source.
22. Lack of amylo-(1,4 to 1,6) transglycolase (branching enzyme)  
   B. Inability to use lactose as an energy source.
23. Lack of UDP-glucose epimerase  
   C. Inability to use galactose as an energy source, with no effect on ability to utilize glycogen.
24. Lack of ability to synthesize glucose 1,6 bisphosphate (a required cofactor for phosphoglucomutase)  
   D. Inability to use either galactose or glycogen as an energy source.
25. Lack of fructose 1,6 bisphosphate phosphatase  
   E. Inability to convert TCA cycle intermediates to fructose 1,6 bisphosphate.
26. Lack of UDP-glucose pyrophosphorylase  
   F. Production of unbranched glycogen.
   G. Inability to convert either glycogen or lactate to free glucose, with no effect on ability to use galactose as an energy source.
   H. Inability to re-synthesize glucose-6-phosphate from lactic acid.

27. (1 point) Which of the following would be potential effects if a drug were developed which inhibited citrate export from the mitochondria within the liver? This question may have more than one correct answer: indicate all correct answers on the answer sheet.

   A. Inability to oxidize fatty acids  
   B. Inability to produce five carbon sugars  
   C. Inability to synthesize fatty acids  
   D. Inability to export glucose  
   E. Inability to synthesize and export chylomicrons  
   F. Inability to synthesize cholesterol
Questions 28-31 (2 points each) are based on the following scenario. Consider a medical student who has been unable to eat since the beginning of exam week five days ago. Answer the questions based on the metabolic state of this individual as they are taking the biochemistry exam, still having gone without food for the past five days. Choose the ONE best answer to each question. An answer may be used once, more than once, or not at all in answering the questions.

28. Primary mechanism for maintaining blood glucose levels
   A. Chylomicrons
   B. Fatty acid oxidation
   C. Fatty acid synthesis
   D. Free fatty acids
   E. Gluconeogenesis

29. Primary pathway through which the liver generates energy
   F. Glucose
   G. Glycogenolysis
   H. Glycogen synthesis
   I. Glycolysis
   J. Ketone bodies

30. An alternate fuel supply for the nervous system

31. The primary fuel supply for the resting muscles

32. (1 point) Which TWO of the following statements are CORRECT concerning the pathways of fatty acid synthesis and fatty acid oxidation?

A. Fatty acid synthesis requires a dehydration reaction, whereas fatty acid oxidation requires a hydration reaction.
B. Fatty acid synthesis utilizes NADPH, whereas fatty acid oxidation generates NADPH.
C. Fatty acid synthesis utilizes FADH2 whereas fatty acid oxidation generates FADH2.
D. Fatty acid synthesis occurs in the cytoplasm whereas fatty acid oxidation occurs in the mitochondria.
E. Fatty acid synthesis is activated by a kinase, whereas fatty acid degradation is inhibited by a kinase activity.
F. Insulin promotes fatty acid degradation whereas glucagon promotes fatty acid synthesis.
33. (2 points) Consider the synthesis of net oxaloacetate starting with only ribose-5-phosphate as the sole carbon source. Which of the following enzymes would NOT be required to effect this conversion? This question may have more than one correct answer. Indicate all correct answers on the answer sheet.

A. Aconitase
B. Glucose-6-phosphate dehydrogenase
C. Glyceraldehyde-3-phosphate dehydrogenase
D. Pyruvate carboxylase
E. Pyruvate dehydrogenase
F. Pyruvate kinase
G. Transketolase

34. (1 point) Consider the situation in which a cell is synthesizing fatty acids, but does not require five carbon sugars. The ribulose-5-phosphate which is produced by the HMP shunt pathway is converted back into glucose-6-phosphate. Indicate below which enzymes are NOT required for this to occur. This question may have more than one correct answer; indicate all correct answers on the answer sheet.

A. Aldolase
B. Glyceraldehyde-3-phosphate dehydrogenase
C. Phosphohexose isomerase
D. Pyruvate carboxylase
E. Transaldolase
F. Transketolase

35. (1 point) Glutathione acts as an anti-oxidant in erythrocyte membranes due to primarily which ONE of the following?

A. It binds vitamin E
B. It binds vitamin C
C. It contains a carbon-carbon double bond which can be reversibly oxidized and then reduced by glutathione reductase
D. It contains two free sulfhydryl groups which can be reversibly oxidized and then reduced by glutathione reductase
E. It contains a conjugated double bond system which can trap electrons and donate them to superoxide dismutase
36. (1 point) A high calorie diet (greater than required for the individual’s BMR and activity level) will lead to the upregulation of all of the following enzymes EXCEPT for which ONE?

A. Acetyl-CoA carboxylase  
B. Citrate lyase  
C. Fatty acid synthase  
D. Glucose-6-phosphate dehydrogenase  
E. Malic enzyme  
F. Transketolase

37. (1 point) All of the following agents can aid in protecting against oxygen radical damage EXCEPT for which ONE?

A. β-carotene  
B. Glutathione peroxidase  
C. Superoxide dismutase  
D. Vitamin B6  
E. Vitamin C  
F. Vitamin E

38. (1 point) Tolerance to certain drugs can arise by which ONE of the following mechanisms?

A. Induction of superoxide dismutase  
B. Induction of glutathione peroxidase  
C. Induction of specific cytochrome P450 systems  
D. Induction of alcohol dehydrogenase  
E. Induction of glucose-6-phosphate dehydrogenase

39. (1 point) Elevated levels of ketone bodies can be found in the blood of untreated type I diabetics and in individuals on severe diets. A major difference (or differences) in the laboratory findings of metabolites in the blood of each type of individual (type I diabetic versus the dieter) would be which of the following? This question may have more than one correct answer; indicate all correct answers on the answer sheet.

A. Free fatty acid levels  
B. Glucose levels  
C. Lactate levels  
D. Six and eight carbon dicarboxylic acid levels  
E. Thiamine pyrophosphate levels
Questions 40-43 (2 points each) are based on the following situation. A type I diabetic has neglected to take insulin for 72 hours, but has eaten normally during this period. Indicate for each question if the compound indicated in the question would be at the same level, or a greater level, or a reduced level, than measuring the compound in an individual who did not have type I diabetes. There is only ONE answer per question, and an answer may be used once, more than once, or not at all.

40. Blood glucose levels
A. The same
41. Blood ketone body levels
B. Greater than the “normal”
42. Blood fatty acid levels
C. Less than the “normal”
43. Blood insulin levels

44. (1 point) In order to sprint effectively, muscle ATP should be generated by which ONE of the following pathways?
A. TCA cycle only
B. TCA cycle and oxidative phosphorylation
C. HMP shunt, TCA cycle, and oxidative phosphorylation
D. Glycolysis only
E. Glycolysis, TCA cycle, and oxidative phosphorylation
F. HMP shunt only

45. (1 point) Weight loss in humans might be achieved by pharmacologically altering which of the following? This question may have more than one correct answer; indicate all correct answers on the answer sheet.
A. Inhibiting leptin production
B. Blocking glycogen synthase activity
C. Activating lipoprotein lipase
D. Activating HMG-CoA reductase
E. Activating muscle UCP-2
F. Inhibiting insulin release
46. (1 point) An individual has a BMR of 3000 Calories per day. The individual then changes their diet to one in which their daily consumption is 100 grams of carbohydrates, 200 grams of protein, and 100 grams of fat. After 30 days on such a diet, without any change in physical activity, what would happen to their weight? Choose the ONE best answer.

A. No change in weight
B. A gain in weight
C. A loss of weight
D. Not enough data to draw a conclusion

Questions 47-51 (2 points each) are based on the following scenario. Consider an individual who has reduced caloric intake to only 500 Calories per day (the BMR for this individual is 2000 Calories per day). After seven days on this diet indicate the activity and phosphorylation state of the following liver enzymes. There is only one answer per question, and an answer may be used once, more than once, or not at all.

47. Phosphorylase kinase
48. Acetyl-CoA carboxylase
49. Pyruvate kinase
50. HMG-CoA reductase
51. Carnitine acyl-transferase I

A. Active and phosphorylated
B. Inactive and phosphorylated
C. Active and not phosphorylated
D. Inactive and not phosphorylated

52. (1 point) Type II diabetics display elevated blood glucose levels, but do not typically contain elevated levels of ketone bodies in their blood. This is most likely due to which ONE of the following?

A. HMG-CoA synthase is inactive in type II diabetics
B. Cholesterol synthesis is enhanced in type II diabetics, removing HMG-CoA from ketone body synthesis
C. The adipocyte can respond to the low levels of insulin released by the pancreas, and fatty acid release is inhibited
D. The hepatocyte can respond to the low levels of insulin released by the pancreas and fatty acid oxidation is inhibited
E. HMG-CoA reductase is inhibited in type II diabetics
53. (2 points) A deficiency of which of the following proteins would be sufficient all by itself (i.e. if present as the only defect), to cause steatorrhea in which all three classes of dietary lipids, TG, PL and CE, were present at elevated levels in the stools. This question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet.

A. Pancreatic lipase
B. Colipase
C. Phospholipase
D. Cholesterol esterase
E. 7-α-hydroxylase
F. Cholecystokinin

54. (2 points). Which of the following symptoms should you be concerned with in patients with steatorrhea? There may be more than one correct answer to this question; be sure to indicate all correct answers on the answer sheet.

A. Reduced bone density
B. Difficulty with vision under low light levels
C. Orange tonsils
D. Type II diabetes
E. Hypertension
F. Slow blood clotting times
G. None of the above

Questions 55-59 (3 points each) should be answered from the lettered list below. Each question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet. An answer may be used once, more than once, or not at all.

55. Which of the potential answers is/are components of mixed micelles?
   A. Cholesterol esters
   B. Triacylglycerol
   C. 2-Monoacylglycerol
   D. Free fatty acids
   E. Taurocholic acid
   F. Phospholipids
   G. apolipoprotein B-48
   H. apolipoprotein B-100
   I. apolipoprotein C-II
   J. apolipoprotein C-III
   K. apolipoprotein E

56. A deficiency of colipase would be expected to interfere with the digestion of which of the potential answers?

57. Which of the potential answers is/are NOT found in mature chylomicrons?

58. Formation of chylomicron remnants from chylomicrons and IDL from VLDL requires the presence of which of the potential answers?

59. Uptake of chylomicron remnants, IDL or LDL involves which of the potential answers?

60. (2 points) In the absence of apolipoprotein E HDL is still taken up by the liver due to the
A deficiency of which protein would be expected to result in the accumulation of excess triglycerides in adipocytes? 
A. Lingual lipase  
B. Pancreatic lipase  
C. Co-lipase  
D. Lipoprotein lipase  
E. Hormone sensitive lipase  
F. ACAT  
G. LCAT  
H. CETP  
I. Hepatic lipase

Questions 61-64 (2 points each) should be answered from the lettered list below. In this case, select the ONE best item which matches the question. An answer may be used once, more than once, or not at all.

61. A deficiency of which protein would be expected to result in the accumulation of excess triglycerides in adipocytes? 
A. LDL receptor  
B. LRP receptor  
C. ABC-1  
D. LPL  
E. SR-B1 receptor

62. A deficiency of which protein would be expected to result in the presence of triglyceride rich LDL and HDL particles? 

63. A deficiency of which protein would be expected to impair the ability of cells to store cholesterol.

64. Inhibition of the activity of this protein would be expected to elevate levels of HDL

Questions 65-68 (2 points each) should be answered from the lettered list below (choices A-C). A patient with the heterozygous form of familial hypercholesterolemia has been prescribed one of the statins. For each of the processes or activities listed below, indicate whether this treatment is likely to increase (answer A), decrease (answer B) or leave unchanged (answer C) the process or activity in the question. There is only ONE answer per question, although an answer may be used once, more than once, or not at all.

65. LDL receptor synthesis
66. Formation of cholesterol esters
67. 7-α-hydroxylase activity
68. HMG-CoA reductase activity

A. Increase
B. Decrease
C. Leave unchanged

(3 points) Which of the following items are NOT part of the process of returning
cholesterol from peripheral tissues to the liver (i.e. reverse cholesterol transport)? This question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet.

A. apoB100  
B. apoA1  
C. Cholesterol esterase  
D. LCAT  
E. chylomicrons  
F. apoE  
G. SR-B1  
H. ABC-1  
I. LPL

70. (2 points) Elevated serum LDL levels stimulate which of the following atherogenic processes? This question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet.

A. Chemoattraction of monocytes  
B. Formation of foam cells  
C. Increased concentrations of oxidized LDL  
D. Decreased hepatic uptake of HDL  
E. Increased synthesis of chylomicrons

Questions 71-75 (1 point for each correct answer) refer to the pathway below. Missing intermediates are indicated by the question number. From the answers below, indicate how these intermediates should be ordered. Each answer should be used only one time.

\[
\text{AcCoA} \rightarrow \text{HMG} \rightarrow (71) \rightarrow (72) \rightarrow \text{Geranyl pyrophosphate} \rightarrow (73) \rightarrow (74) \rightarrow (75) \rightarrow \text{Cholesterol}
\]

A. Farnesyl pyrophosphate  
B. Mevalonate  
C. Isopentenyl pyrophosphate  
D. Lanosterol  
E. Squalene
Questions 76-77 (2 points each) should be answered from the lettered list below. In your endocrinology practice you have recently seen two patients with symptoms consistent with decreased levels of serum cortisol, raising your suspicion that they may have adrenal deficiencies. In both cases a careful history further suggests that the underlying etiology may be congenital. From the list of enzymes below, select the ONE which is most likely to be deficient in each of the two patient histories which follow.

76. Analysis of the first patient's levels of steroid hormones confirms the absence of cortisol and also reveals very low levels of estradiol with normal levels of aldosterone.  
A. 11-α-Hydroxylase  
B. Desmolase  
C. 3-α-Hydroxysteroid dehydrogenase  
D. 17-α-Hydroxylase  
E. 21-α-Hydroxylase  
F. 7-α-Hydroxylase

77. The second patient's blood workup reveals reduced levels of cortisol, 11-Deoxycortisol, 11-Deoxycorticosterone and aldosterone with normal levels of testosterone and androstenedione.  

78. (3 points) Obesity places an added burden on the pancreas to produce insulin, leading to down regulation of insulin receptors and eventually to exhaustion of the insulin producing capacity of the β-cells. In the pathway below, leading from obesity to insulin receptors, every lettered intermediate increases in concentration EXCEPT for which THREE?

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79. (2 points). An individual with a total serum cholesterol level of 210 mg/dl, a serum HDL-cholesterol of 50, and a serum triglyceride level of 150 would be calculated to have an LDL cholesterol of which ONE of the following?

A. 100  
B. 130  
C. 160  
D. 190  
E. 220  
F. 300  
G. None of the above

80. (2 points) Which of the following items have been shown to result in decreased body fat and weight loss? There may be more than one correct answer to this question; indicate all correct answers on the answer sheet.

A. Increased levels of TNF-α  
B. Decreased levels of acetyl CoA carboxylase  
C. Increased levels of HMG CoA reductase  
D. Decreased activity of fatty acid synthase
E. Increased levels of 7-α-Hydroxylase

81. (2 points) Insulin and glucagon act via pathways involving the regulation of cAMP levels in cells. Which of the following processes are increased by elevated levels of cAMP in the liver or adipose tissue? This question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet.

A. Synthesis of triglycerides
B. Formation of free fatty acids from triglycerides
C. Synthesis of cholesterol
D. Synthesis of bile acids
E. Synthesis of cortisol
82. (2 points) Which of the following statements are correct concerning bile acids? This question may have more than one correct answer; be sure to indicate all correct answers on the answer sheet.

A. In the absence of HMG CoA reductase they cannot be synthesized
B. They are conjugated with taurine or glycine by intestinal bacteria
C. When conjugated with glycine or taurine, they become more soluble at low pH
D. About half of the bile acids and bile salts that are secreted into the duodenum are excreted in the feces
E. When bound in the intestine by resins such as cholestyramine or colestid, the activity of hepatic 7-α- hydroxylase is elevated.

Questions 83-85 (1 point each) are based on the lettered list below (choices A-D). Match the appropriate answer with the term in the question. There is only ONE answer per question, and an answer may only be used once in this set of questions.

83. β-lipoproteins  
84. Pre-β lipoproteins  
85. α-lipoproteins  

83. A. Chylomicrons  
84. B. VLDL  
85. C. LDL  
86. D. HDL

86. (2 points). Individuals homozygous for the E-2 isoform of apolipoprotein E have dysbetalipoproteinemia. This disease is associated with which of the following laboratory findings? This question may have more than one correct answer. Be sure to indicate all correct answers on the answer sheet.

A. Elevated chylomicrons  
B. Elevated serum triglyceride  
C. Elevated serum cholesterol  
D. β-Migrating remnant particles  
E. Increased hepatic binding affinity of IDL
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