This exam consists of two parts. Part I is multiple choice. Each of these 25 questions is worth two points. Answer the Part I questions on this sheet, below. Answer the Part II questions on the question pages.

Please use BLOCK CAPITAL letters like this ---  A, B, C, D, E. Not lowercase!

1. ___D___  
2. ___C___  
3. ___E___  
4. ___C___  
5. ___D___  
6. ___A___  
7. ___C___  
8. ___A___  
9. ___E___  
10. ___A___  
11. ___A___  
12. ___D___  
13. ___D___  
14. ___C___  
15. ___A___  
16. ___C___  
17. ___D___  
18. ___B___  
19. ___D___  
20. ___E___  
21. ___D___  
22. ___A___  
23. ___B___  
24. ___B___  
25. ___B___

GRADE:

Part I Total _______

Part II:

II-1 _______
II-2 _______
II-3 _______
II-4 _______
II-5 _______

Part II Total _______

Total, I & II _______
1. The starting material for Glycogen Synthase is glycogen and what?
   A. Glucose    D. UDP Glucose
   B. Glucose-1-P  E. Fructose-6-P
   C. Glucose-6-P

2. What is the intracellular message conveyed by Fructose 2,6 Bisphosphate?
   A. too much calcium    D. high energy charge
   B. not enough glucose  E. low energy charge
   C. lots of glucose

3. Glycogen Phosphorylase b can be *allosterically* activated by
   A. Ca++    D. G6P
   B. cAMP     E. AMP
   C. Insulin

4. When ATP = 7 mM, ADP = 2 mM, and AMP = 1 mM the Atkinson Energy
   Charge equals what?
   A. 10    D. 0.7
   B. 0.9    E. –0.21
   C. 0.8

5.* The graph at right represents the activity of (what enzyme) as (what substrate) is
   varied?
   A. Protein Kinase A, cAMP    D. PFK-1, ATP
   B. G6Pase, G6P     E. FBPase, ATP
   C. Aldolase, F-1,6-BP
Third examination

6. Facilitated diffusion through a biological membrane is:
   A) Driven by the difference in transmembrane solute concentration;
   B) Driven by ATP;
   C) Not saturable by the transported substrate;
   D) Driven by an electrochemical proton gradient;
   E) Not specific with respect to the substrate.

7. Which type of membrane transport systems uses ATP hydrolysis as an energy source?
   A) Facilitated diffusion;
   B) Simple diffusion;
   C) Primary active transport;
   D) Ionophores;
   E) Ion channels.

8. Which of the following statements is true about the specificity filter of the potassium channel
   A) Differential interaction with potential oxygen ligands in the selectivity filter protein are
      responsible for its selectivity;
   B) Specificity depends upon the hydrophobicity of the channel;
   C) Specificity is influenced by the phospholipid composition of the channel;
   D) Specificity depends on the presence of carbohydrates in the channel;
   E) Specificity requires the presence of protons in the channel.

9. Which of the following transport systems is capable of mediating both symport and antiport?
   A) Ion channels;
   B) ABC transporters;
   C) Simple diffusion of nonpolar solutes;
   D) Facilitated diffusion;
   E) Secondary active transport

10. Which of the following is true about photochemical reaction centers?
    A) Cyanobacteria and plants have two reaction centers arranged in tandem;
    B) Cyanobacteria contain a single reaction center of the Fe-S type;
    C) Green sulfur bacteria have two reaction centers arranged in tandem;
    D) Plant photosystems have a single reaction center of the pheophytin-quinone type;
    E) Purple bacteria contain a single reaction center of the Fe-S type.

11. What is the sequence of events that is elicited upon absorption of a photon of light by PSII?
    A) P680 is excited to P680*, an electron is passed to pheophytin, and then to plastoquinone;
    B) P700 is excited to P700*, an electron is passed to chlorophyll $A_0$, and then to phyllo-
       quinone;
    C) P870 is excited to P870*, an electron is passed to bacteriopheophytin, and then to ubi-
       quinone;
    D) P840 is excited to P840*, an electron is passed to a quinone, and then to the $b_{6f}$ complex;
    E) P680 is excited to P680*, an electron is passed to ferredoxin, and then to FNR.
12. During photophosphorylation in plants, electrons flow through a series of carriers arranged in a Z scheme in which:
   A) P700 serves as the electron donor, ferredoxin as the ultimate acceptor, and CO$_2$ provides the energy to move the electrons;
   B) H$_2$S serves as the electron donor, NAD$^+$ as the ultimate acceptor, and ATP provides the energy to move the electrons;
   C) Organic acids serves as the electron donor, cytochrome $c_2$ as the ultimate acceptor, and pyrophosphate provides the energy to move the electrons;
   D) H$_2$O serves as the electron donor, NADP$^+$ as the ultimate acceptor, and light provides the energy to move the electrons;
   E) None of the above is correct.

13. Among the unique components of the cytochrome $b_{6}f$ complex is a chlorophyll molecule which is thought to function in:
   A) Resonance energy transfer;
   B) Charge separation across the thylakoid membrane;
   C) The primary photochemical event;
   D) Photoprotection of the $b_{6}f$ complex against singlet O$_2$ formation by an electron transfer mechanism;
   E) Cyclic electron transfer with PSI.

14. Which statement best fits the structure-function relationships in PSI?
   A) It is arranged in a dimeric form that contains the OEC and Try$_z$ to reduce photooxidized P700
   B) It contains its core antenna chlorophylls in CP47 and CP43
   C) It exist as a trimeric structure in Cyanobacteria that contains an extensive array of chlorophylls, which efficiently use solar energy
   D) It is present in stacked grana lamellae where it collects 850 nm photons with high efficacy
   E) None of the above.

15. After fatty acids are activated to acyl-CoAs, the acyl group is further transferred to carnitine because:
   A) acyl-carnitines readily cross the mitochondrial inner membrane, but acyl-CoAs do not;
   B) acyl-CoAs easily cross the mitochondrial membrane, but fatty acids themselves will not;
   C) carnitine is required to oxidize NAD$^+$ to NADH;
   D) fatty acids cannot be oxidized by FAD unless they are in the acyl-carnitine form;
   E) None of the above is true.

16. Which of the following statements apply to the $\beta$ oxidation of fatty acids?
   A) The process takes place in the cytosol of mammalian cells;
   B) Carbon atoms are removed from the acyl chain one at a time;
   C) Before oxidation, fatty acids must be converted to their CoA derivatives;
   D) NADP$^+$ is the electron acceptor;
   E) The products of $\beta$ oxidation are converted to ketone bodies that function as waste products.
17. Which of the following statements concerning the β oxidation of fatty acids is true?
A) NADPH and FMNH₂ serve as electron donors;
B) One FADH₂ and two NADH are produced for each acetyl-CoA;
C) The free fatty acid must be carboxylated in the β position by a biotin-dependent reaction before the process of β oxidation commences;
D) The free fatty acid must be converted to a thioester before the process of β oxidation commences;
E) Two NADH are produced for each acetyl-CoA.

18. Ketone bodies are formed in the liver and transported to the extrahepatic tissues mainly as:
A) acetoacetyl-CoA;
B) β-hydroxybutyric acid;
C) β-hydroxybutyryl-CoA;
D) lactic acid;
E) Acetone.

19. Which liver mitochondrial enzyme involved in ketone body formation has a cytosolic isozyme that catalyzes an early step in cholesterol biosynthesis?
A) Enoyl-CoA hydratase;
B) β-Hydroxyacyl-CoA oxidoreductase;
C) HMG-CoA reductase;
D) HMG-CoA synthase;
E) Mevalonate phosphotransferase.

20. Which of the following is not required in the synthesis of fatty acids?
A) Acetyl-CoA;
B) Biotin;
C) HCO₃⁻ (CO₂⁻);
D) Malonyl-CoA;
E) NADH.

21. If malonyl-CoA is synthesized from ^1⁴CO₂ and unlabeled acetyl-CoA, and the labeled malonate is then used for fatty acid synthesis, the final product (fatty acid) will have radioactive carbon in:
A) Every C;
B) Every even-numbered C-atom;
C) Every odd-numbered C-atom;
D) No part of the molecule;
E) Only the omega-carbon atom (farthest carbon from C-1).

22. In comparing fatty acid biosynthesis with β oxidation of fatty acids, which of the following statements is incorrect?
A) The enzymes that catalyze the synthetic path in vertebrates form complexes of the separate catalytic polypeptide chains, while the oxidative enzymes are part of a single polypeptide chain containing all of the distinct enzyme activities;
B) A thioester derivative of D-β-hydroxybutyrate is an intermediate in the synthetic path, but not in the degradative path;
C) Fatty acid biosynthesis uses NADPH exclusively, whereas β oxidation uses NAD⁺ exclusively;
D) Fatty acid degradation is catalyzed by enzymes of the mitochondrial matrix; fatty acid synthesis by cytosolic enzymes;
E) Intermediates of fatty acid biosynthesis are activated by thioester linkages to acyl carrier
protein, while the intermediates of fatty acid oxidation are CoA linked.

23. The enzyme system for adding double bonds to saturated fatty acids requires all of the following except:
   A) An iron containing desaturase; B) ATP;
   C) cytochrome b₅; D) molecular oxygen;
   E) NADPH.

24. In the synthesis of phosphatidylcholine from phosphatidylethanolamine, the methyl group donor is:
   A) A tetrahydrofolate derivative;
   B) S-adenosylmethionine (adoMet);
   C) Methanol;
   D) Choline;
   E) Serine.

25. Which of the following is not an intermediate in the synthesis of cholesterol from acetyl-CoA?
   A) Isopentenyl pyrophosphate;
   B) Malonyl-CoA;
   C) Mevalonate;
   D) Squalene;
   E) β-Hydroxy-β-methylglutaryl-CoA (HMG-CoA).
PART II Answer these questions here on the question pages.

1. a. Draw β-D-Ribofuranose.

   ![β-D-Ribofuranose](image)

   (2 points)

b. Insulin stimulates PPI which then acts on three substrates. What is PPI? What are the three substrates?

   N.C. (Protein Phosphatase I or Phosphoprotein Phosphatase) + 1  (1) Glycogen Phosphorylase (a)

   + 1  (2) Phosphorylase Kinase

   + 1  (3) Glycogen Synthase

   (3 points)

c. Diagram the Glycogen Breakdown cascade, starting with Epinephrine and ending with active Phosphorylase. Include cofactors where appropriate.

   ![Glycogen Breakdown Cascade](image)

   (5 points)

   One point per check

   • EPI (αG protein NOT REQUIRED)
   • Adenylate Cyclase
   • ATP → cAMP
   • Protein Kinase A → "ON"
   • Phosphorylase Kinase → "ON"
   • Phosphorylase b → "ON" or "a"
2. Provide an example of an ion-selective channel and list three factors that distinguish it from an ion transporter

The prokaryotic K⁺ channel is an ion-selective plasma membrane channel (4 points)

They are distinguished from ion transporters by: (2 points each)
   1. Very rapid ion flux;
   2. Their lack of saturability;
   3. Their ligand or voltage gating.

3. Show how photosynthetic and heterotrophic organisms exist in a balanced steady state and discuss how evolution of the heterotrophs was driven by photosynthetic organisms.

(7 points)
Photosynthetic organisms trap solar energy and form NADPH and ATP as energy sources for making carbohydrates and other reduced organic compounds from CO₂ and H₂O, releasing O₂ into the atmosphere

Aerobic heterotrophs use the O₂ as the terminal electron acceptor in the degradation of the energy rich products of photosynthesis to CO₂ and H₂O, generating ATP

The CO₂ is recycled back into the atmosphere to be fixed into new organic compounds by photosynthesis

(3 points)
O₂ arising from Cyanobacterial photosynthesis drove the evolution of animal life
4. The β oxidation of fatty acids begins with this activation reaction:

\[
R-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{COOH} + \text{ATP} + \text{CoA-SH} \rightarrow R-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CO-S-CoA} + \text{AMP} + \text{PP}_i
\]

What are the next two steps (after transport into the mitochondria)? Show structures and indicate where any cofactors participate and how they enter the respiratory chain.

Acyl CoA dehydrogenase:

5. What are plasma lipoproteins (2 points)? Discuss the structure of two of the lipoproteins and their general roles in mammalian metabolism (4 points each)?

Chylomicron

Low density lipoprotein
TAGs, cholesterol and other lipids are carried by plasma lipoproteins – two examples showing their compositions are presented.

Use any two lipoproteins from this list:

**Chylomicrons** – triacylglycerols (TAGs) are incorporated into lipid core of chylomicrons (lipoprotein class consisting mostly of TAGs and apolipoprotiens)

TAG-rich chylomicrons are transported via lymphatics ---> blood stream ---> muscle and adipose tissue for oxidation and storage.

**Low density lipoprotein (LDL)** is synthesized in the liver and is the major transporter of cholesterol and cholesterol esters from liver to extrahepatic tissues

**High density lipoprotein (HDL)** -- Cholesterol esters synthesized by LCAT, located on surface of nascent HDL particles, form an HDL core which transforms the nascent particles into mature spherical HDL.

The cholesterol-rich HDL particles return to the liver from extrahepatic tissues, where the cholesterol is unloaded and is largely excreted in bile salts

**Very low density lipoprotein (VLDL)** delivers endogenously synthesized TAGs from liver to adipose and other tissues