Instructions: This exam is out of 100 points, you should allot 1 min/2 pts. Please use the space provided or the back of the previous page. On questions with more than one choice, all of your attempts will be graded and you will receive the grade for your best attempt.

1. (4 pts) Briefly explain why the scattering of X-rays by electrons can be used to determine the structure of proteins.

The scattering depends on the relative position of one atom relative to another (3 pts) leading to constructive or destructive interference (1 pt).

Acceptable – the scattering is used to generate an electron density map into which atoms are placed to generate the structure.

2. (5 pts) Please do one of the following two choices.

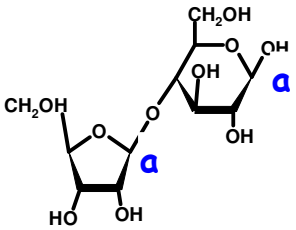
Choice A: How do the chair and boat forms of a sugar differ (a diagram is a suitable answer) (2 pts)? Why might one chair form be more stable than the other chair form (3 pt)?

Chair forms have one end of the sugar up and one down.

Boat form has both ends of the ring up.

One chair may be higher in energy than the other due to crowding of axial –OH groups leading to repulsive van der Waals forces.

Choice B: Label the anomeric carbons in the dissacharide shown on the right (1 pt). Circle the correct name for this disaccharide. If you would like partial credit for an incorrect answer, justify your answer (4 pts).

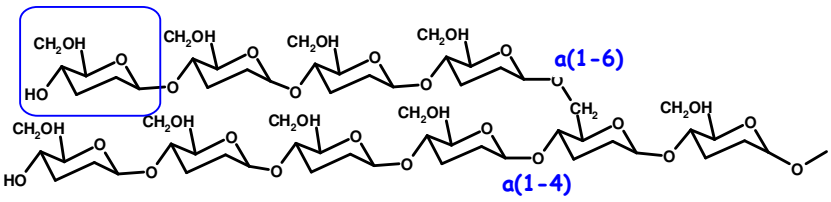


a. β-glucopyranosyl-(4-1) β-ribofuranose
b. α-ribofuranosyl-(1-4)-β-glucopyranose
c. β-ribofuranosyl-(1-4)-β-glucofuranose
d. β-ribofuranosyl-(1-4)-β-glucopyranoside
e. β-ribofuranosyl-(1-4) β-glucopyranose

Give partial credit (3 pts) for wrong answer with good justification.

3. (4 pts) The structure on the right represents a glycogen molecule.

i) Name and identify the glycosidic bond(s) found in this polysaccharide (3 pts) **1 ½ pts each.**



ii) Circle the glucose that would be released as glucose-1-P by glycogen phosphorylase **(1 pt)**

4. (6 pts) Please do one of the following choices.

Choice A: What is the overall structure of a bacterial cell wall? How does the structure explain the high mechanical strength of the cell wall?

Linear polysaccharides made of alternating NAG and NAM (modified glucose) **(3 pts)**

Are cross linked by peptide chains between the NAM units on adjacent strands **(2 pts)**

The covalent crosslinking provides high strength. **(1 pt)**

Choice B: What is the polysaccharide that plays a structural role in plants? Name the monosaccharide used to form the polysaccharide and the linkage between the individual units.

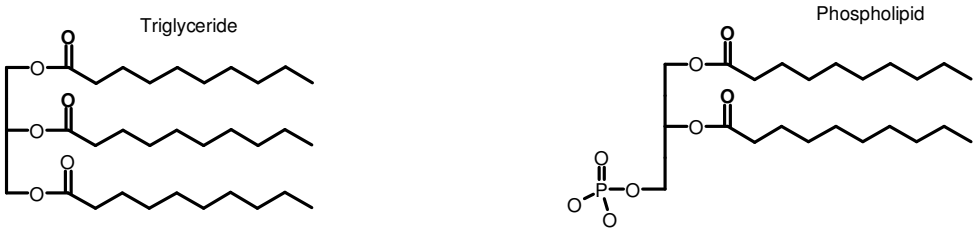
Cellulose **(1 pt)**

Glucose **(2 pts)**

β(1-4) linkage **(3 pts)** **[any discussion of branching -1 pt]**

5. (8 pts) Please answer both parts of this question

i) Using the partial structure below, draw **either** a triglyceride **or** a phospholipid. Take care to add any missing atoms to the existing diagrams (2 pts) **(-1 pt for no O in ester)**



ii) What type of structure is formed when **phospholipids** are mixed with water? What thermodynamic force drives the formation of this structure? (6 pts).

- Bilayers are formed – with the polar head groups on the exterior and the acyl chains on the interior **(3 pts)**
- This is due to the hydrophobic effect. **(3 pts)**

6. (6 pts) Please do one of the following choices.

Choice A: Which of the following fatty acids would show the lowest critical micelle concentration (CMC): a) hexanoic acid (C_6) or b) decanoic acid (C_{10}). *Briefly justify your answer* (6 pts).

Choice B: Briefly describe why introducing a cis double bond into a fatty acid leads to a large drop in the melting temperature.

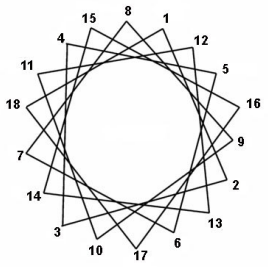
Choice A: The fatty acid (b) with the most non-polar part should show the smallest CMC, or concentration when micelles begin to form. **(4 pts)** This is due to a larger hydrophobic effect which will stabilize micelles at a lower concentration. **(2 pts)**

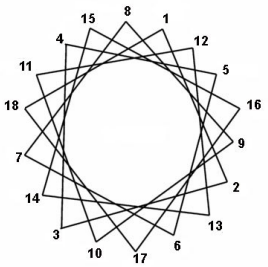
Choice B: The cis double bond kinks the chain **(3 pts)** – which reduces van der Waals contacts, **(3 pts)** lowering the melting temperature.

7. (3 pts) Which of the following features of cholesterol are *incorrect* (circle **all** that apply)

a) It contains rigid non-polar rings.
b) It contains a flexible non-polar tail.
c) It is part of the electron transport chain
d) It contains a polar –OH group.
e) It causes membranes to be more rigid at all temperatures.

8. (12 pts) An integral membrane protein consists of two α-helical segments that are imbedded in the membrane. A "top view" of this protein is shown on the right. Briefly discuss the following aspects of the structure of this protein.

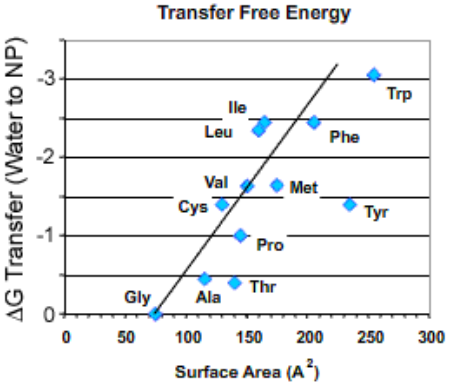




i) What other type of secondary or super-secondary structures are seen in membrane proteins. *Why?*

ii) What is the distribution of polar and non-polar residues along the polypeptide sequence and how does this distribution relate to the interaction of the protein with the membrane?

iii) Residues that contact the lipid are generally large and non-polar. Why are small non-polar seldom found? The diagram on the right may be useful.



i) β-barrel, both the helix and the barrel are structures that satisfy mainchain H bonding. This is important because there are no H-bond donor or acceptors in the membrane.

ii) The residues exposed to the lipid will be non-polar. Using the left helical wheel as an example, residues 3, 7, 11 would be non-polar, i.e. every 3rd or 4th residue.

iii) The energetic cost to insert the polar mainchain atoms into the bilayer is unfavorable, (by +1 kcal/mol). Therefore the sidechain must be large enough such that the transfer energy exceeds this. Anything larger than Ala will do.

9. (6 pts) Please do one of the following choices.

Choice A: Briefly explain why the potassium channel is selective for potassium.

Choice B: The potassium channel has been referred to as an enzyme. In which ways is it similar to other enzymes (e.g. serine proteases), in which ways is it different?

Choice C: The concentration of potassium outside the cell is 1 mM and the concentration inside is 1 mM. The voltage potential across the membrane is +0.1V, with the inside positive. What direction will potassium flow, into the cell, or out of the cell? *Justify your answer using (but not necessarily calculating) the Gibbs free energy, ΔG.*

Choice A: The ion must be dehydrated as it passes through the channel. The energy loss due to this dehydration is replaced by favorable interactions between the K+ and the C=O groups in the channel. Na+, being smaller, doesn't form the same low energy interactions, and therefore remains hydrated.

Choice B: It catalyzes the rate of K+ movement by lowering the activation energy (+3 pts). It doesn't chemically change its substrate, but moves the substrate across the membrane.

Choice C:

$\Delta G = RT \ln [K^+ \text{ in}]/[K^+ \text{ out}] + ZF\Delta V$

The first term is zero since the concentrations inside and outside are equal

The second term is (+1)(96,000)(+0.1) which is positive. Therefore the reaction is spontaneous in the reverse direction, the K+ flows out.

10. (10 pts) The conversion of A to B in a metabolic pathway (A→B→C) has a standard energy change (ΔG^o) of +20 kJ/mol. Propose a method that could be used to make this reaction spontaneous (+8 pts). Give an example of this method in an actual metabolic pathway (+2 pts).

The reaction A to B could be directly coupled to ATP hydrolysis in some way, making ΔG^o negative, and therefore ΔG negative **(+6 pts)**
Examples include the phosphorylation of Glucose to G-6-P and Fructose-6-P to Fructose 1,6 P.**(2 pts)**

The reaction B to C could be made to be very favorable. This would make the concentration of [B] lower than its equilibrium level, thus the RT ln[B]/{A] term will be negative, making ΔG negative. **(+6 pts)**
The reaction PEP (phosphoenol pyruvate) to pyruvate accomplishes this in glycolysis. .**(2 pts)**

11. (8 pts) Please do one of the following choices:

Choice A: Give a brief overview of the fate of carbon atoms in the metabolism of glucose **or** a fatty acid, **your answer should include**:

i) the names of the pathways
ii) changes to the number of carbons atoms in the intermediates of the pathways.
iii) the final fate of carbon atoms.
iv) the cellular location of the pathways.

Choice B: How are allosteric effects related to ATP synthesis during oxidative phosphorylation in the mitochondria?

Choice A: (6 pts for correct flow of carbon, 2 pts for location of pathways.)
Glucose – glycolysis (cytosol) – Pyruvate – CO_2 produced – acetyl CoA – TCA cycle (2 CO_2 lost)
TCA cycle is in the matrix of the mitochondria.
Oxidation of **Fatty acids** to produce acetyl-CoA occurs in the matrix with no loss of carbon, Fatty acids, enter the TCA cycle in the matrix, where carbon is released as CO_2

Choice B:
Passage of protons through ATP synthase **(2 pts)** cause allosteric changes in the β-subunits. Focusing on one subunit. **(6 pts)**

- The first state has low affinity for everything,
- the second state has affinity for ADP and Pi, so they bind
- The conformation of the last state makes ATP more stable than ADP+Pi, so ATP is spontaneously formed.
- Return to the first conformation releases the ATP.

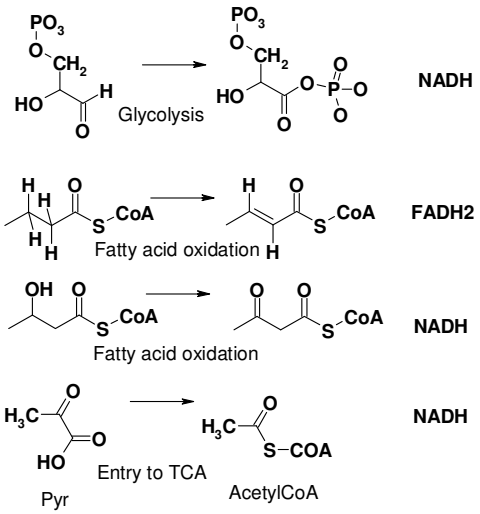
12. (5 pts) Correct these sentences (if necessary).

i) A ~~feedback~~ inhibitor resembles the product of the reaction that it regulates.
Product **(1 pt)**

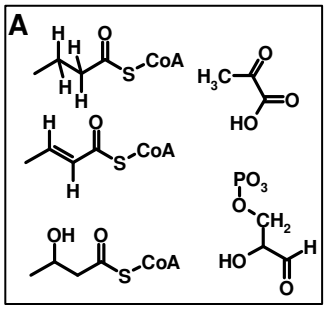
ii) A ~~phosphatase~~ adds a phosphate group to a protein, generating ADP.
Kinase **(2 pts)**

iii) In yeast cultures grown under low oxygen conditions, ~~three~~ moles of ethanol are produced
two **(1 pt)**
per mole of glucose. This process conserves ~~less~~ than half of the original energy in the glucose.
More **(1 pt)**

13. (10 pts) Please complete **all** parts of this question:



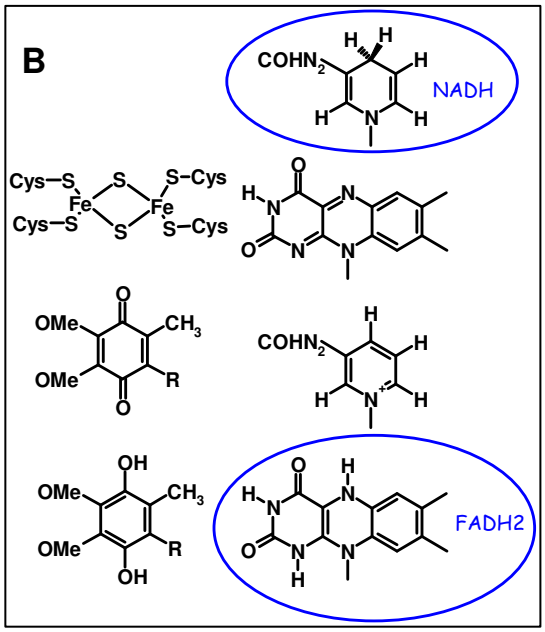
i) Give an example of an oxidation reaction in any metabolic pathway. State the pathway that the reaction occurs and either describe the reaction or draw the reactant and product. A few possible **reactants** are shown in box A (2 pts).



ii) Give the *general* name for enzymes that catalyze such reactions (1 pts). **Dehydrogenase**

iii) Box B shows the structure of a number of electron donors and acceptors. Circle the compound which would be the immediate product of the reaction you chose as an example **(1 pts). (-1/2 for NAD/FADH2 reversal)**

iv) The electrons from the compound you circled in box B progress through the electron transport pathway. State the cellular location of this pathway, and list the steps in the pathway (in the correct order), ending with the final electron acceptor (5 pts).



Electron transport occurs in the inner mitochondrial matrix (1 pt)

NADH – Complex I – Q- Complex III-cytochrome C-Complex IV-O_2 (4 pts)

FADH2 – Complex II – Q- Complex III-cytochrome C-Complex IV-O_2 (4 pts)

v) The energy that is released during electron transport is stored as **proton (hydrogen ion) gradient (1/2) across the inner membrane (1/2 pt)** (complete the sentence) (1 pts)?

14. (5 pts) Why are an individual's glycogen levels generally lower if they are on a high fat diet?

Carbon from fat is converted to Acetyl-CoA, which cannot be converted to pyruvate to enter gluconeogenesis.
(Accepted for partial credit – a high fat diet implies low carbs, so there isn't much glucose present to make glycogen.)

15. (8 pts) Please do **one** of the following choices (choices A & B involve glucolysis/gluconeogenesis regulation, choice C involves regulation of glycogen storage and degradation).

Choice A: Briefly describe how the regulation of glycolysis and gluconeogenesis in a liver cell is responsive to the energy needs of the cell.

Choice B: Briefly describe how the glycolysis and gluconeogenesis in a liver cell is responsive to hormonal signals that regulate blood glucose levels. Select one hormone as an example.

Choice C: Briefly describe how glycogen synthesis and degradation in the liver cell is responsive to hormonal signals that regulate blood glucose levels. Select one hormone as an example.

[You don't need to use all of this space for this question.]

Key points: Regulation makes biological sense.
Opposing pathways are regulated in a coordinate manner.

Choice A:

- High levels of ATP, which indicate high energy reserves inhibit PFK in glycolysis.**(2 pts)** This is appropriate since glycolysis generates ATP.**(2pts)**
- High levels of AMP/ADP, which indicate low energy reserves activate PFK in glycolysis. This is appropriate since glycolysis will convert the ADP/AMP back to ATP.**(2 pts)**
- AMP inhibits fructose bis phosphatase in gluconeogenesis. This is appropriate because you don't want both pathways on at the same time.**(2 pts)**

Choice B:

- **Glucagon/epinephrine** are secreted to indicate glucose demand, or that the liver should make glucose.
- These hormones cause enzyme phosphorylation that leads to a decrease in the level of F26P
- F26P is required for activation of PFK in glycolysis, so it is off, glucose will not be oxidized.
- F26P no longer inhibits fructose bis phosphatase in gluconeogenesis, therefore glucose is produced from pyruvate.
- **Insulin**: is secreted to indicate high levels of blood glucose. The liver should store the glucose or use it in glycolysis to make ATP. Everything listed above in reverse:
- Enzymes are dephosophorylated
- F26P levels climb
- PFK (glycolysis) is activated, fructose bis phosphatase (gluconeogenesis) is inhibited.

Choice C:

- Glucagon/epinephrine are secreted to indicate glucose demand, or that the liver should make glucose.
- These hormones cause enzyme phosphorylation.
- Glycogen phosphorylase, which releases glucose from glycogen is active, glucose is released by the liver.
- Glycogen synthase, which adds glucose to glycogen is inactive.
- Insulin: is secreted to indicate high levels of blood glucose. The liver should store the glucose or use it in glycolysis to make ATP. Everything listed above in reverse:
- Enzymes are dephophorylated
- Glycogen synthase is active, glucose is stored in glycogen,. Glycogen phosphorylase is inactive.