1. 20 pts. Fill in the blanks (2 points each.)

A. At low concentrations of substrate, an enzyme catalyzed reaction is first order with respect to _substrate_ and _enzyme_, but at high concentration of substrate, it is zero order with respect to _substrate_.

B. A _substrate_ analog is typically a competitive enzyme inhibitor, but a _Transition state_ analog is often an irreversible inhibitor.

C. Draw an omega-3 polyunsaturated fatty acid.

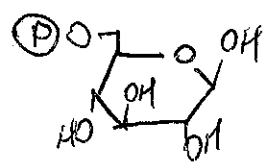
D. _Cholesterol_ is a steroid that modulates cell membrane fluidity.

E. Proteins which have carbohydrates covalently attached are known as _glycoproteins_; the carbohydroate portion of membrane associated proteins are on the _exterior_ face of the cell membrane.

F. _DAG or IP_3_ is one of the second messengers produced though the α-adrenergic receptor signal transduction pathway.

G. The binding target of a lipid hormone/receptor complex within nuclear DNA is called a _hormone response element_.

H. Draw the β anomer of D-6-phosphoglucose.



I. Sucrose is not a reducing sugar because it does not have _a hemiacetal (open chain form)_.

J. _Catabolism_ is the part of metabolism in which nutrients are broken down for energy.

2. 10 pts. Write True or False (1 points each)

A. __True__ A competitive inhibitor is relatively most effective at low concentrations of substrate, but an uncompetitive inhibitor is relatively most effective at high concentrations of substrate.

B. __True__ Allosteric enzymes do not obey Michaelis-Menton kinetics.

C. __False__ Phosphoenolpyruvate is a positive effector of the enzyme phosphofructokinase that acts by stabilizing the tense state of the enzyme.

D. __True__ In order to form an energetically favorable structure, a transmembrane β-sheet must form a barrel to satisfy all of it backbone hydrogen bonds.

E. __True__ In some situations, it is a spontaneous process for positively charged ions to flow into a cell even if it has a positive membrane potential.

F. __False__ The sodium/potassium ATPase is an example of a pump that uses secondary active transport to move its ions.

G. __False__ Starch and glycogen are similar in most ways except that one polymer has α glycosidic bonds and the other has β glycosidic bonds.

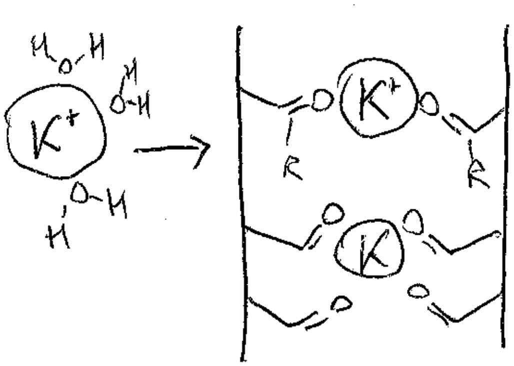
H. __True__ NAD^+ is the oxidized form of a cofactor that is able to accept two high energy electrons.

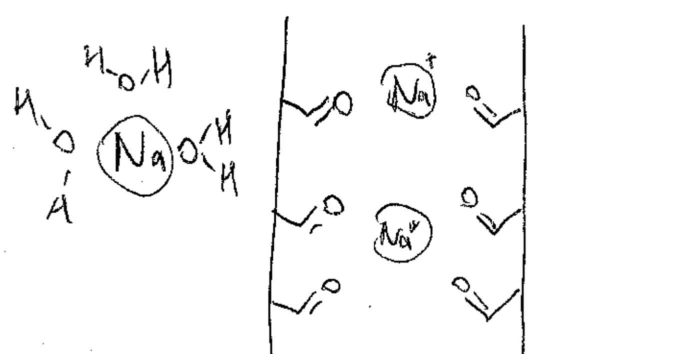
I. __False__ Near equilibrium reactions have standard free energy close to zero.

J. __True__ The hydrolysis of ATP to ADP and P_i has a large negative standard free energy when the ratio of products to reactants is equal to K_{eq}.

3. 20 pts. Short answer (5 points each)

A. Explain, with words and a picture, how the potassium ion channel is able to exclude a smaller sodium ion from crossing a membrane.

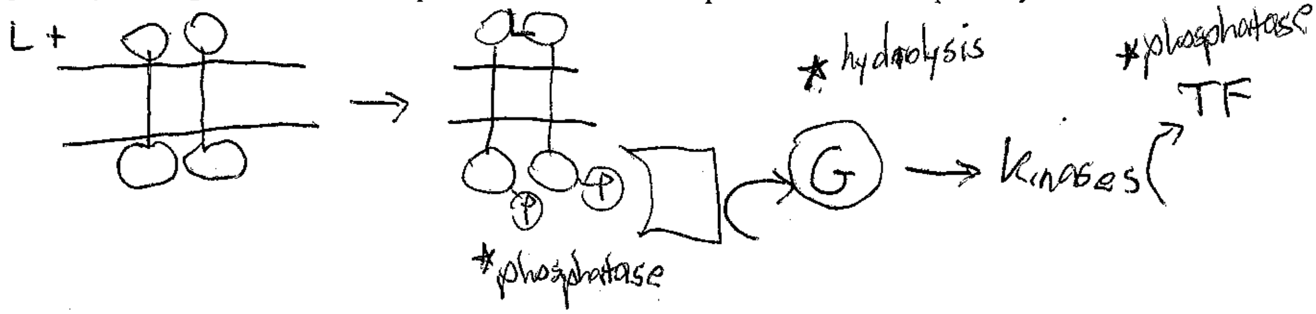




When K+ loses its hydration shell, it is stabilized in the channel!

Na+ is too small to be coordinated effectively in channel.

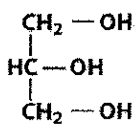
B. Using Epidermal Growth Factor as an example, draw a simple diagram of a receptor tyrosine kinase pathway leading to altered transcription factors. Label two points at which the pathway can be turned off.



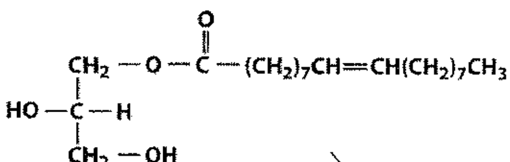
C. Circle the compounds below that could form bilayers.

(a) $CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COO^-$

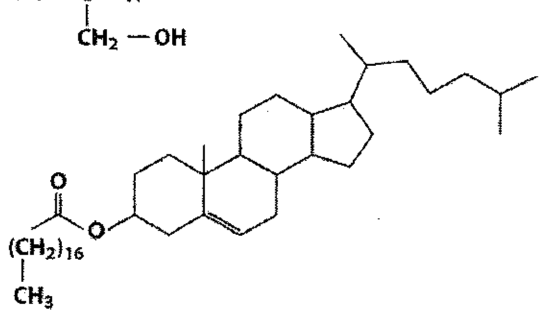
(b)



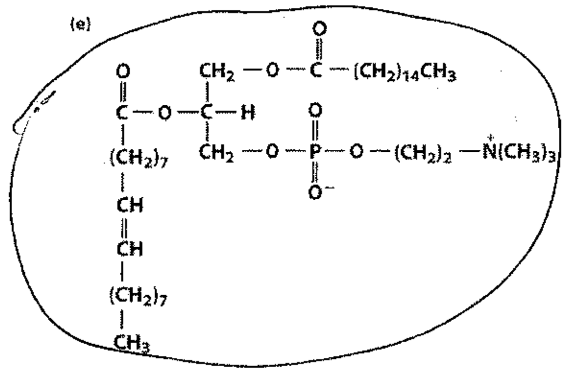
(c)



(d)



(e)



D. Glycophorin A is a 131-residue integral protein that includes one bilayer-spanning segment. Identify that segment in the following sequence. What type of structure is this membrane spanning segment?

LSTTEVAMHTTTSSSVSKSYISSQTNDTHKRDTYAATPRAHEVSEISVRTVYPPEEETGER
VQLAHHFSEPEITLIIFGVMAGVIGTILLISYGIRRLIKKSPSDVKPLPSPDTDVPLSSVEIEN
PETSDQ

An α helix

Section 2: Problems (10 points each)

4. You have recently been investigating a metabolic enzyme that has a K_M of 100 mM and a catalytic efficiency (specificity constant) of $4.0 \times 10^7\ M^{-1}s^{-1}$. You ran the experiment with 1.5×10^{-9} M enzyme.

A. What is V_{max} for this enzyme-mediated reaction?

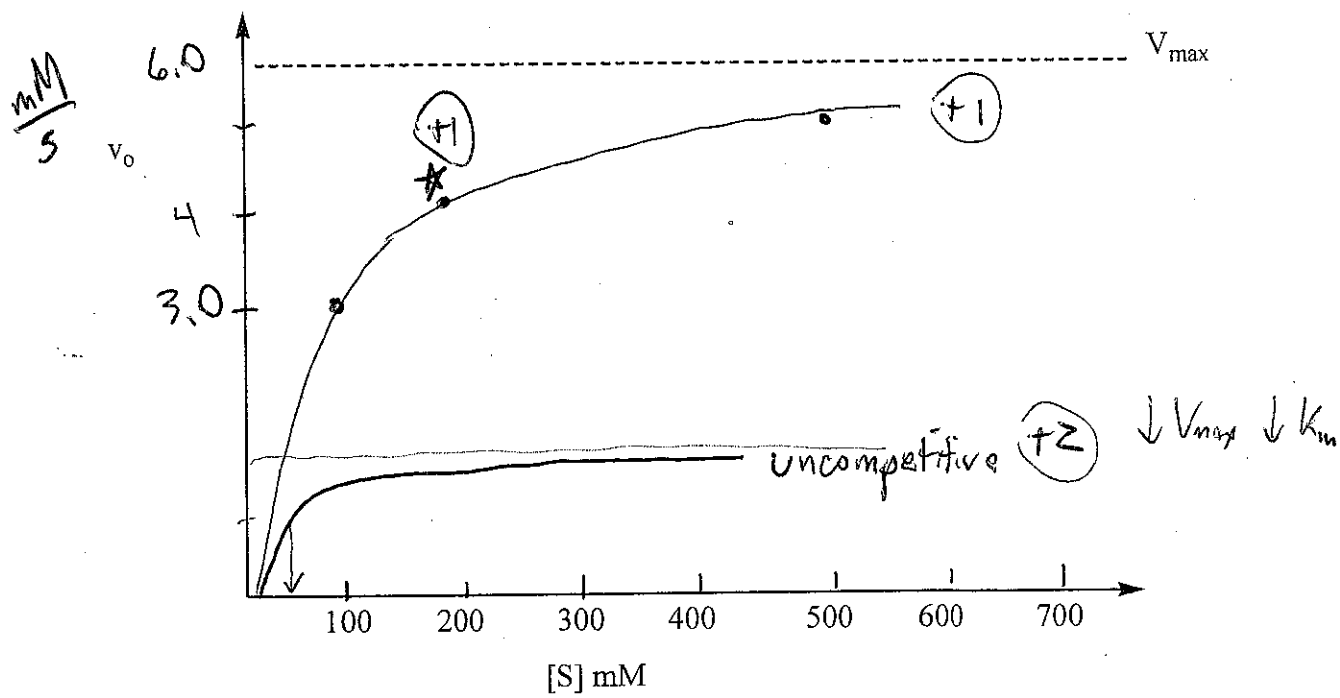
$$\frac{k_{cat}}{K_m} = 4.0 \times 10^7\ M^{-1} s^{-1} = \frac{k_{cat}}{0.1\ M}$$

$$k_{cat} = 4.0 \times 10^6\ s^{-1}$$

$$V_{max} = [E] k_{cat} = 6.0 \times 10^{-3}\ \frac{M}{s}$$

+4

B. Draw a Michaelis-Menton graph of velocity as a function of substrate for this reaction. Mark the curve with an asterisk (*) at the point on the curve that is the velocity of the reaction at $2K_M$. Then draw a curve on the same graph for the enzyme if it were treated with an uncompetitive inhibitor.



C. What is the velocity of this reaction when 1.5×10^{-9} M enzyme is mixed with 100 mM substrate?

$$3.0 \times 10^{-3}\ \frac{M}{s}$$

+2

5. Calculate the standard free energy for the formation of ATP from creatine phosphate according to the reaction below:

Creatine phosphate + ADP → creatine + ATP

Creatine phosphate → creatine + P_i $\Delta G^{\circ\prime} = -43.1 \frac{kJ}{mol}$

$ADP + P_i \rightarrow ATP$ $\Delta G^{\circ\prime}$ $+30.5$

$\Delta G^{\circ\prime}$ $-12.6 \frac{kJ}{mol}$

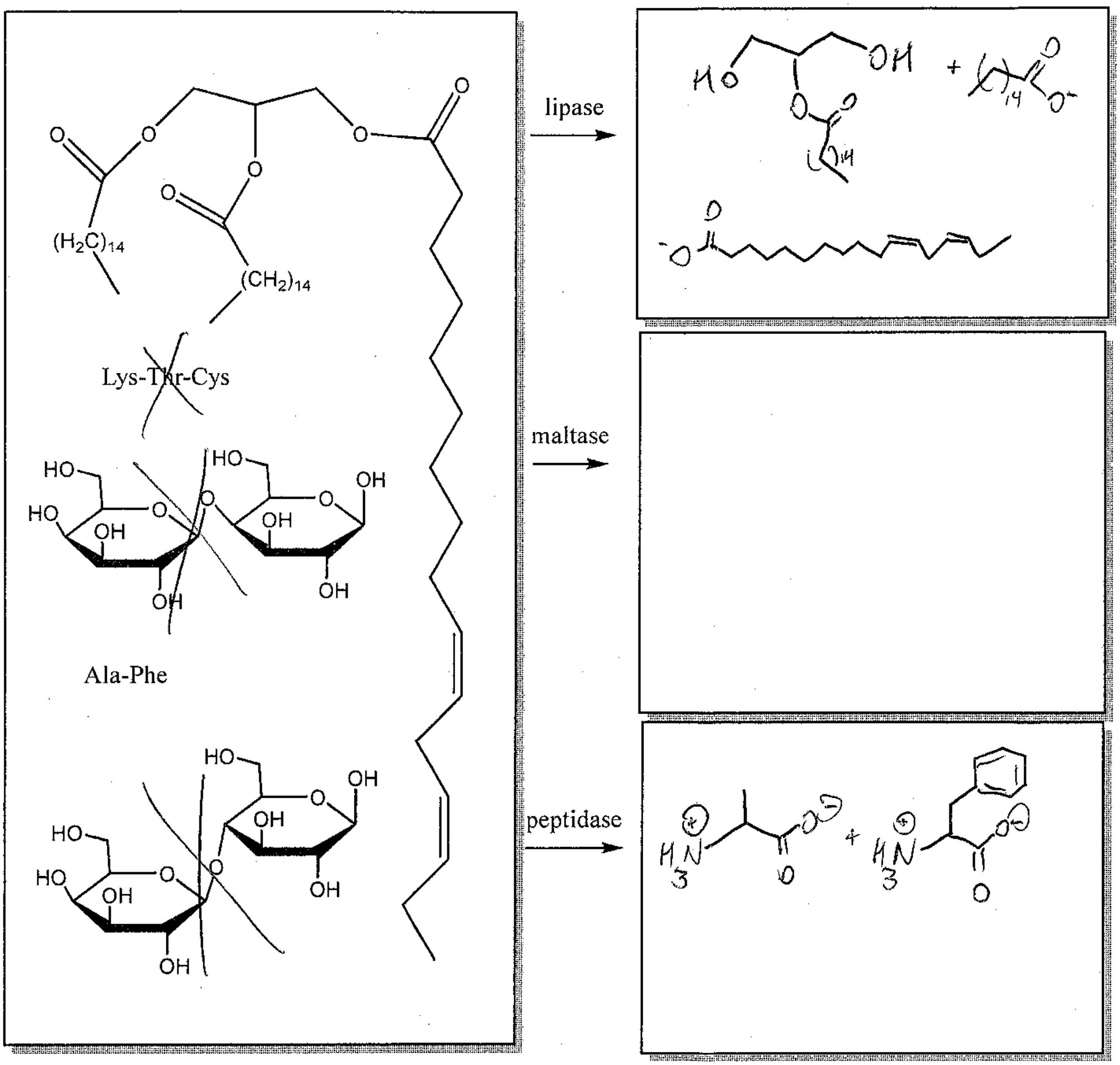
Resting muscle has a creatine concentration of about 0.5 mmol and a creatine phosphate concentration of about 5 mmol. Resting muscle has significantly more ATP than ADP, but when muscle is used strenuously, the concentration of ATP can drop to the point that it is equal to the concentration of ADP. Under cellular conditions of exercised muscle, what is the free energy of phosphate transfer from creatine phosphate to ADP?

$$\Delta G' = \Delta G^{\circ\prime} + RT \ln \frac{[Cr][ATP]}{[CrP][ADP]}$$

$$= -12600 \frac{J}{mol} + 8.314 \frac{J}{mol\,K}(310\,K) \ln \frac{[0.0005\,M]}{0.005\,M}$$

$$= -18.5 \frac{kJ}{mol}$$

6. A mixture of dietary components entering the intestine encounter a mixture of pancreatic digestive enzymes: lipase (which produces free fatty acids and monoacylglycerols), maltase (which hydrolyzes the α (1→4) linkage of glucose disaccharides), and a peptidase that is specific for dipeptides. Put an "X" through any of these compounds in the box on the left if they will not be digested. In the boxes on the right, draw full structures of the products of each enzyme catalyzed reaction.



7. The sodium-potassium pump is trying to pump 3 sodium ions out of the cell from 12 mM concentration to a 145 mM concentration, while also trying to pump 2 ions potassium in to the cell from a concentration of 4 mM to 155 mM at a temperature of 310 K. If the membrane potential for this cell is -60mV, how much energy is required for this process?

(+6)

Sodium: $\Delta G' = 8.314 \frac{J}{mol\,K}(310) \ln \frac{.145}{.012} + (+1)(96485 \frac{J}{mol\,V})(.060\,V)$

$\Delta G' = 6.4\,kJ + 5.8\,kJ = 12.2 \frac{kJ}{mol}(3\,Na^+) = 36.6 \frac{kJ}{mol}$

Potassium: $\Delta G' = 8.314 \frac{J}{mol\,K}(310) \ln \frac{.155}{.004} + (+1)\,96{,}485 \frac{J}{mol\,V})(-.060\,V)$

x3, x2 } -1

Δψ -1

$\Delta G' = 9.4 \frac{kJ}{mol} + -5.8 \frac{kJ}{mol} = 3.6 \frac{kJ}{mol}(2\,K^+) = 7.2 \frac{kJ}{mol}$

Total $\Delta G' = +43.8 \frac{kJ}{mol}$

The pump utilizes the hydrolysis energy of ATP to ADP and Pi to accomplish this ion transfer. If the standard free energy of ATP hydrolysis is about -32 kJ/mol, and the free energy under physiological concentrations of ATP, ADP, and Pi is -48 kJ/mol, will the pump be able to work under these conditions? Explain.

(+4)

Yes. Coupling ATP hydrolysis to pumping gives

$\Delta G' = 43.8 \frac{kJ}{mol} + -48 \frac{kJ}{mol} = -4.2\,kJ$

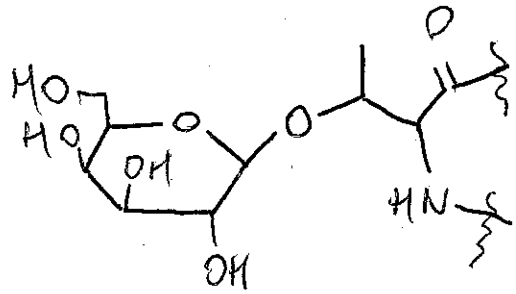
a negative ΔG', so it is spontaneous.

- Full credit for any coupling based on part A

8. O-linked glycoproteins.

A. Collagen isolated from a deep-sea hydrothermal vent work contains a glycosylated threonine residue in the "Y" position of the $(Gly\text{-}X\text{-}Y)_n$ repeating triplet. A galactose residue is covalently attached to the threonine via a β-glycosidic bond. Draw the structure of the galactosylated threonine residue.

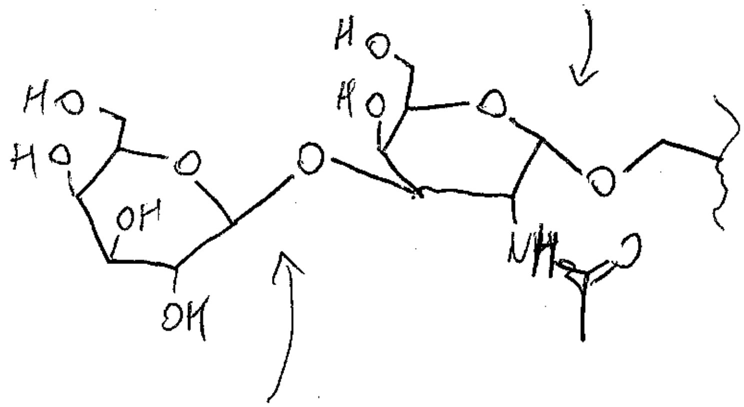
+2 threonine
+3 galactose
+1 β



B. A common O-glycosidic attachment of an oligosaccharide to a glycoprotein is β-galatosyl(1→3)-α-N-acetylgalactosaminyl-Ser. (Galactosamine has an amino group substituted for its hydroxyl group at carbon 2.) Draw the structure of the oligosaccharide and its linkage to the glycoprotein.

+4

+2 serine α linked



+2 β(1→3) linked

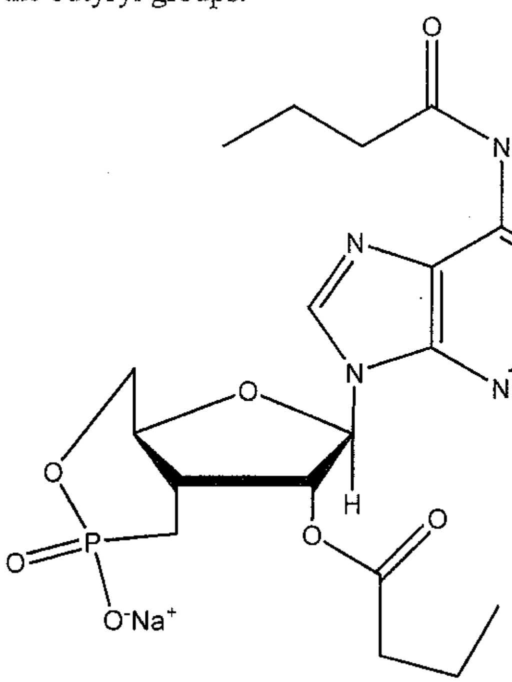
Section 3: Case study (10pts)

The β-adrenergic receptor mediated pathway leading to the release of glucose from stored glycogen was investigated in a cell culture. Predict what will happen to glycogen breakdown in each of these experiments.

A. The cell culture was treated with epinephrine and a nonhydrolyzable analog of GTP.

(+4) Glucose release will start and then continue without stopping. The G-protein is constitutively active because it cannot hydrolyze the GTP analog.

B. The cell culture was treated with dibutyryl cAMP with no epinephrine. Explain the purpose of the butyryl groups.



(+3) - Glycogen breakdown will proceed without ligand because the second messenger cAMP is added directly.

(+3) - The butyryl groups make it capable of crossing the membrane to enter into the cell directly.