MIT Invitational Tournament
Cell Biology Exam

January 24th, 2015

Total Points: 140
Duration: 60 Minutes

Instructions:
This test is composed of 16 pages including this cover. Please check to make sure you have all the pages when you start the exam.

Write all answers on your answer sheet. Do not write in the exam booklet. Work in the exam booklet will not be graded.

If you need more space to answer a question than is provided, please continue your answer on the back of the answer sheet.

Questions marked with an asterisk **(*)** next to the number are tiebreakers.

If you need assistance or have a question, please raise your hand for a proctor.

Be sure you have written your names, school, and team number on the front page of the answer sheet before you hand it in. **Also write your team number on every page of the answer sheet in the top right corner**.

1. For each box, place a check mark in the corresponding box on your answer sheet to indicate that the indicated structure can be present in cells of the given type (1/2 pt per row: 5 pts total)

Part	Plant	Animal	Prokaryote	Structure
(a)				Cell Wall
(b)				Flagellum
(c)				Central Vacuole
(d)				Centriole
(e)				Nucleus
(f)				Nucleolus
(g)				Nucleoid
(h)				Lysosome
(i)				Ribosome
(j)				Plasmodesmata

2. Match each organelle below to the cell type whose function would be most affected if the organelle's activity was disrupted (choices may be used more than once or not at all): (1 pt each: 6 pts total)

1. Chloroplast 2. Peroxisome 3. Smooth ER 4. Rough ER 5. Lysosome 6. Golgi

a) Adipose cells [Synthesize and degrade fatty acids to store or produce energy
b) Mesenchyme cell [Photosynthetic plant cells]
c) Zona Glomerulosa cell [Produces aldosterone, a steroid hormone]
d) Macrophage [Digests bacteria and pathogens]
e) Plasma B cell [Produces antibodies]
f) Neuron [Transmits signals via production of neurotransmitters]

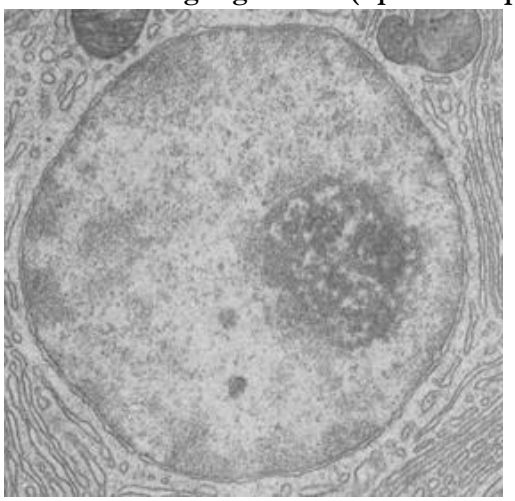
3. (*) After isolating the DNA coding for an important enzyme in human neurons, you have successfully transfected an *E. Coli* culture with the cDNA and expressed your protein. However, after you isolate the product protein, it turns out that the enzyme produced by your *E. Coli* culture is completely nonfunctional! You are certain that you carried out the cloning and protein expression properly. Propose at least two reasons why your product enzyme does not show biological activity. (2 pts)

4. Which of the following would you expect might occur after activation of a G_s GPRC? Select all that apply. (2 pts)

a) PIP is cleaved to yield DAG and IP3
b) Protein Kinase A activity is activated
c) Adenylate cyclase activity is reduced
d) Intracellular calcium levels increase
e) cAMP levels increase

5. Label the following organelles. (1 pt each: 6 pts total)

A



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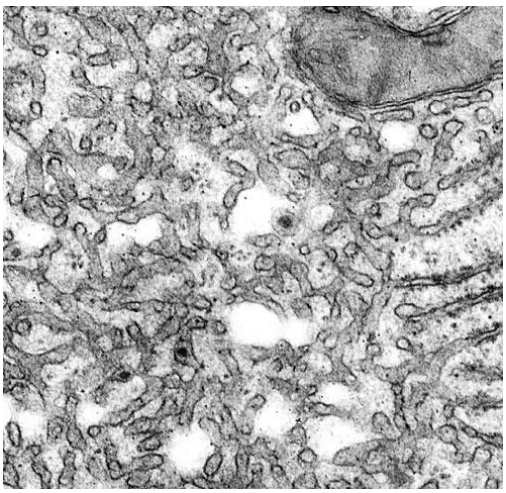

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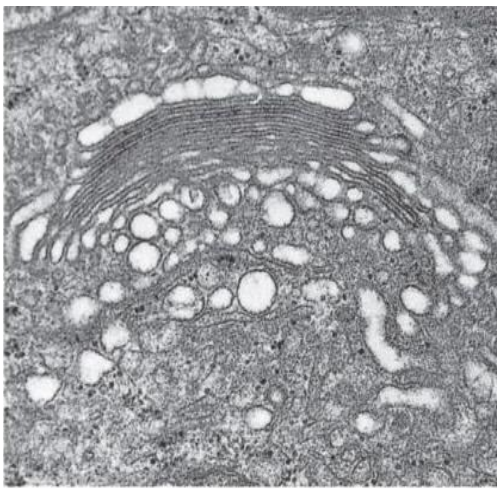

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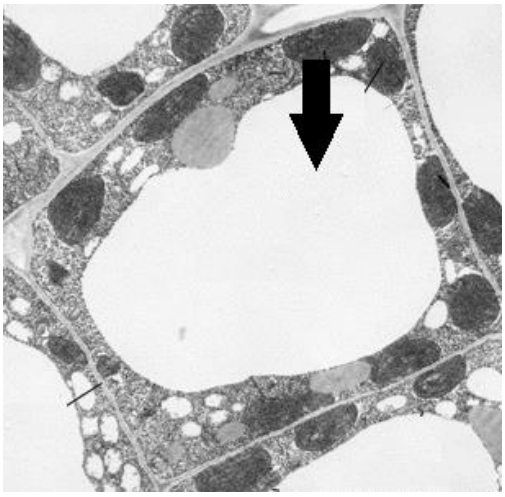

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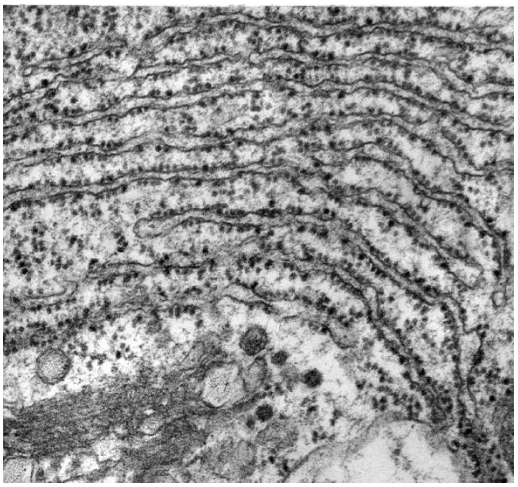

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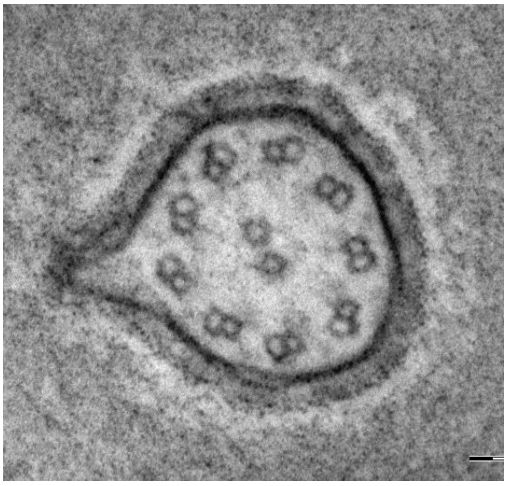
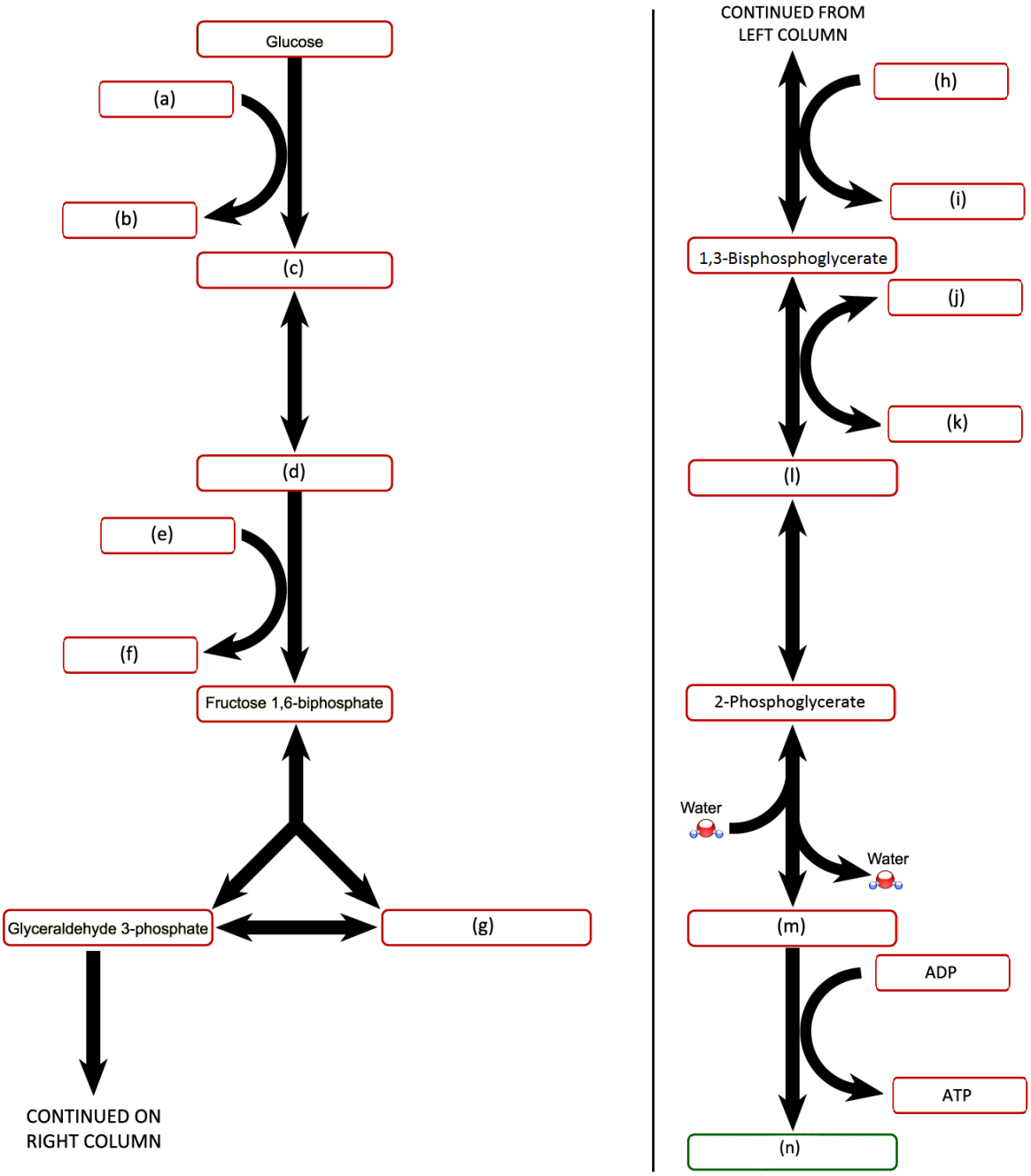


6. Fill in the blank boxes in the glycolysis pathway (10 pts total)



7. What are the net products of glycolysis? (1 pt each: 5 pts total)

a) _____ x ATP
b) _____ x NADH
c) _____ x $FADH_2$
d) _____ x CO_2
e) _____ x Pyruvate

8. What are the net products of the Krebs cycle (per molecule of glucose, including the action of the pyruvate dehydrogenase complex)? (1 pt each: 5 pts total)

a) _____ x ATP
b) _____ x NADH
c) _____ x $FADH_2$
d) _____ x CO_2
e) _____ x Pyruvate

9. How many net ATP molecules are produced for each glucose molecule that is oxidized fully to carbon dioxide through glycolysis, the Krebs cycle, and oxidative phosphorylation? (1 pt)

a) 8-10
b) 24-26
c) 30-32
d) 36-38

10. What is the main purpose of lactic acid fermentation under anaerobic conditions? (1 pt)

a) To directly produce additional ATP for the cell
b) To regenerate NAD^+ for use in glycolysis
c) To prevent the buildup of pyruvate, which is toxic in high concentrations
d) To produce lactic acid for use in other metabolic pathways.

11. Compared to lactic acid fermentation, ethanol fermentation: (1 pt)

a) Produces more ATP
b) Consumes more NADH
c) Is more efficient at converting pyruvate into energy
d) Produces more CO_2

12. UCP1 is an uncoupling protein that can be expressed in the inner membrane of human mitochondria. This protein is an ion transporter that provides an alternative route for protons to move across the inner mitochondrial membrane without passing through ATP synthase. Based on this information, select all of the following statements which are true. (1 pt each: 4 pts total)

a) Increased expression of UCP1 will reduce ATP production by redirecting energetic protons to an unproductive pathway.
b) Increased expression of UCP1 will increase heat generation in the mitochondria.
c) Decreased expression of UCP1 will decrease ATP production because the inner membrane will be less permeable to the protons that produce the electromotive force to generate ATP.
d) Decreased expression of UCP1 will increase the potential difference across the inner mitochondrial membrane

13. Fill in the blanks to reflect the path of an electron through the noncyclic photosynthetic electron transport chain (1 pt each: 6 pts total)

- H2O

a) Photosystem _____

b) _____

c) Cytochrome _____

d) _____

e) Photosystem _____

f) _____

14. Answer the following questions about photosynthesis. (5 pts total)

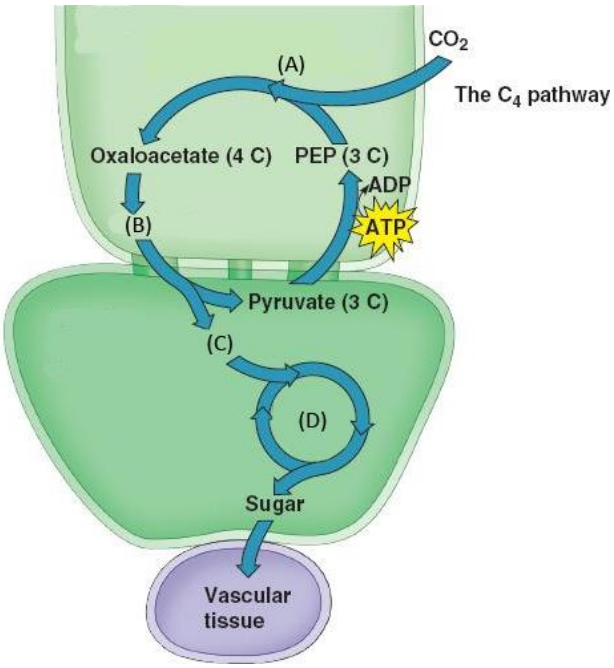
a) What is the difference between cyclic and noncyclic electron flow?

b) Why do plants need cyclic electron flow?

c) What role does NADPH play in catabolism and how does this role differ from ATP?

d) What enzyme fixes carbon in C_3 metabolism? Give the full name for credit.

15. Fill in the missing compounds (a-d) on this diagram of C_4 photosynthesis (1 pt each: 4 pts total)



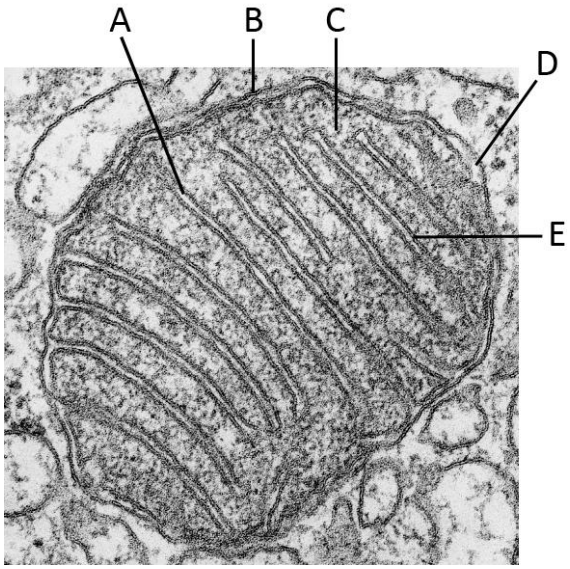
16. (*) Answer the following questions about C_4 photosynthesis. (2pts each: 6 pts total)

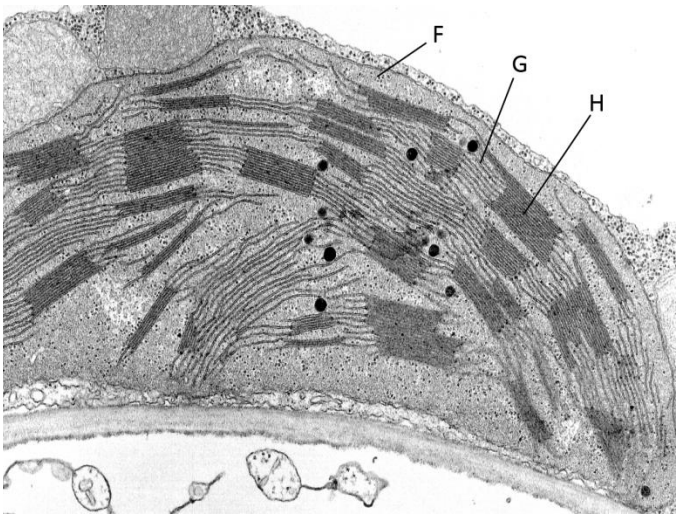
a) What problem does RuBisCo have that makes C_4 photosynthesis more efficient under some circumstances?

b) How does C_4 photosynthesis circumvent this issue?

c) Name another type of photosynthetic pathway that addresses the same issue and explain how it works.

17. Identify the indicated structures (a-h) of the mitochondria and chloroplast shown and answer the following questions (i-l) (9 pts total)





i) In what part of each organelle would you expect the pH to be significantly more acidic than the cytosol? You may write the name of the structure or the corresponding letter.

j) What are the dark granules seen in the chloroplast?

k) How is it theorized that mitochondria and chloroplasts first arose in eukaryotic cells?

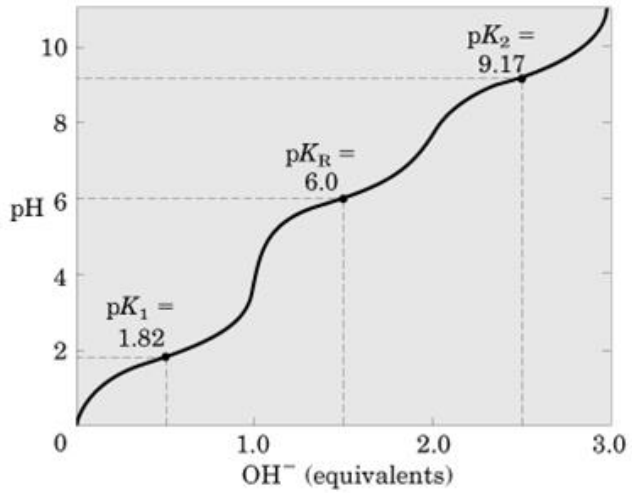
l) Give at least different two pieces of evidence supporting this theory

18. You set out to measure the efficiency of photosynthesis with your trusty photoelectric light meter and your handy gaseous flow meter. Using these instruments, you determine that over the course of 4 hours, a plant with a total surface area of 2 square meters was exposed to an average light intensity of 1 kilowatt per square meter. During this time, it consumed 26.50 grams of CO_2. Please show all work for this question (4 pts total).

a) Assume all the CO_2 consumed by the plant was fixed into glucose. What total mass of glucose was produced during these four hours? Take the molar masses of C as 12g/mol, H as 1g/mol, and O as 16g/mol.

b) Converting one gram of CO_2 to glucose takes 10,800 joules of energy. What was the efficiency of the conversion from light energy into glucose for this plant?

You want to identify a mystery amino acid! First, you titrate the amino acid to yield the following titration curve:



19. From this information, select which statement(s) about this amino acid must be true. (2 pts)

a) This amino acid has a nonpolar side chain
b) This amino acid has a polar but uncharged side chain
c) This amino acid has a carboxyl (-COOH) group *on its side chain*
d) This amino acid has an amine (-NH or $-NH_2$) group *on its side chain*

20. After some mass spectroscopy work, you determine that your mystery amino acid has at least one ring. Which amino acid have you found? (2 pts)

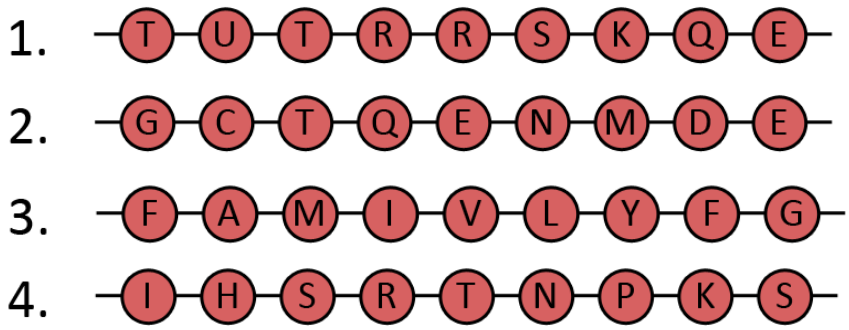
21. Answer the following questions about major classes of polysaccharides: (1 pt each: 4 pts total)

a) What is the major difference between amylose and cellulose that prevents us from digesting the latter?

b) What is the main function of glycogen in the human body?

c) Upon adding an iodine solution to an unknown solution, purple-black granules are immediately observed. What polysaccharide is present?

d) Which polysaccharide is the major component of the cell walls of fungi?



22. (*) Four partial peptide sequences are presented above. Match each functional motif described below with the sequence above that is *most likely* to be found in such a motif and give a short explanation of your reasoning. (1 pt each: 4 pts total)

a) DNA binding (Hint: DNA has a negative charge)
b) Transmembrane section of a G protein receptor
c) Alpha helix
d) Cation chelation/binding

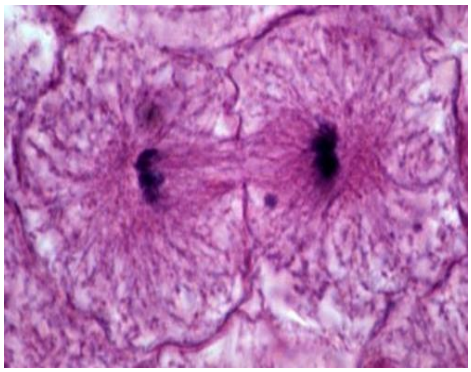
(Please refer to the chart if you are unfamiliar with the amino acid abbreviations)

Amino Acid	"Three-Letter" Abbreviation	One-Letter Abbreviation
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartate	Asp	D
Cysteine	Cys	C
Glutamate	Glu	E
Glutamine	Gln	Q
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y

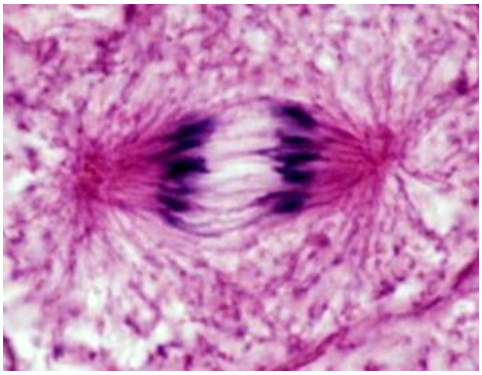
23. Label the stages of mitosis shown below (0.5 pts each: 2 pts total)

A

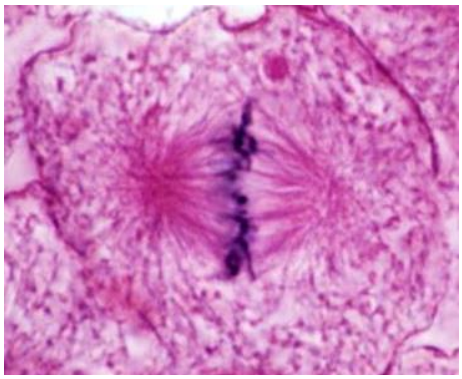
B



C



D



24. You add a compound to a cell culture that prevents the breakdown of cohesin. Cohesin is a protein that binds sister chromatids together. You then induce cellular division and wait for several hours. When you examine the culture under a microscope, you find that almost all of the cells are stuck at one phase of the cell cycle. (1 pt each: 2 pts total)

a) Which phase are these cells in?

b) Explain why these cells stopped at this stage.

25. A certain line of cells has an inducible mutation that protects cyclins from degradation. What effect will the expression of this mutation have on the cells and why? (2 pts)

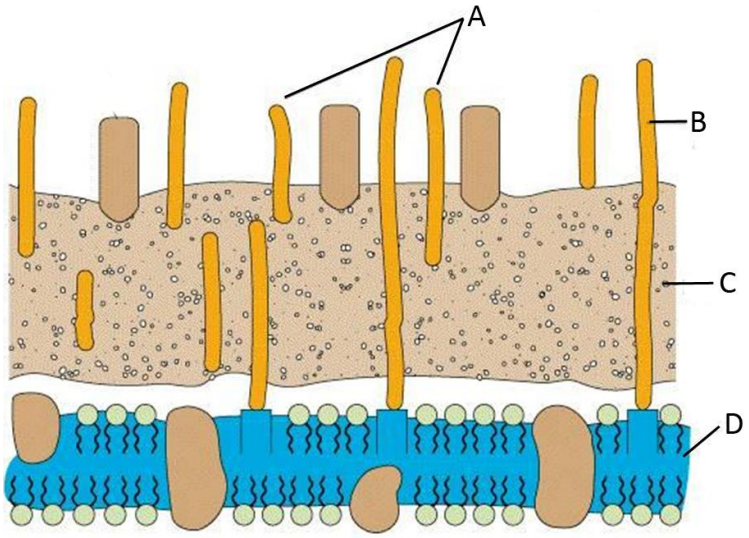
26. You are studying a diploid organism with a sexual lifecycle that has a total of 1 billion nucleotides in its genome. What number of nucleotides you would expect to find in the genome of each cell type of this organism below? (0.5 pts each: 1.5 pts total)

a) Somatic cell in G_0

b) Somatic cell in G_2

c) Germ cell

27. Label the indicated components (a-d) of this gram positive cell wall (4 pts)



28. Draw and label a cross section of a gram negative cell wall in a similar style to the question above. Be sure to indicate which side is cytoplasmic and which side is extracellular. Hint: You should have 4 components labeled. (4 pts)

29. Answer the following questions about membrane structure. (1 pt each: 4 pts total)

a) What class of molecule is the main component of the plasma membrane?

b) What property of these molecules causes them to segregate into membranous structures?

c) What type of interaction dominates between the "tails" of these molecules?

d) What is the purpose of cholesterol in the plasma membrane of animal cells?

30. Which of the following are able to move freely across cell membranes *without* the help of a transporter or pore protein? Select all that apply. (1 pt)

a) Steroid hormones
b) Glucose
c) Oxygen
d) Carbon Dioxide
e) Amino Acids

31. Neurons maintain a resting potential across their membranes. To do this, they must transport ions against their concentration gradients. (0.5 pts each: 1.5 pts total)

a) What type of transport is this?

b) What provides the energy to perform this counter gradient transport?

c) Which ions play key roles in producing this resting potential?

32. (*) Cystic Fibrosis is caused by a mutation in the CFTR gene. The CFTR gene produces a chloride ion transporter that normally allows Cl^- ions to flow freely out of epithelial cells in the lung. When the gene is mutated, Cl- is trapped inside the cells. This leads to the buildup of thick mucus that would normally be fluid enough to leave the lungs, promoting inflammation and infection. Propose a rationale for the symptoms observed in cystic fibrosis. (2 pts)

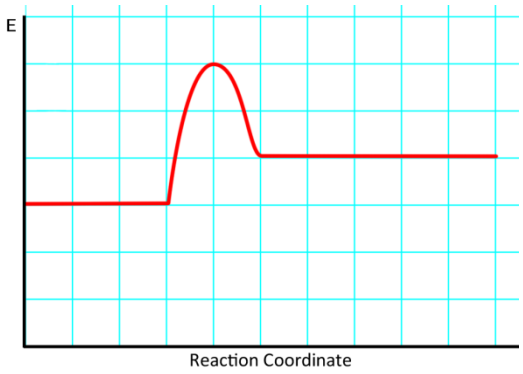
33. Match the following cell processes with their most closely associated cytoskeletal component. (0.5 pts each: 4 pts total)

1. Microfilament **2.** Intermediate Filament 3. Microtubule

a) Epidermal protection from abrasion and liquids
b) Stability of the nucleus
c) Movement of chromosomes during mitosis
d) Cytoplasmic streaming
e) Signal transduction framework in the cellular cortex
f) Cell motility through flagella and cilia
g) Cytokinesis
h) Muscle contraction

34. What two key properties of an enzyme make it a catalyst? (1 pt)

Below is the energy diagram of an uncatalyzed reaction. After the addition of an enzyme, the reaction proceeds much more quickly than before.



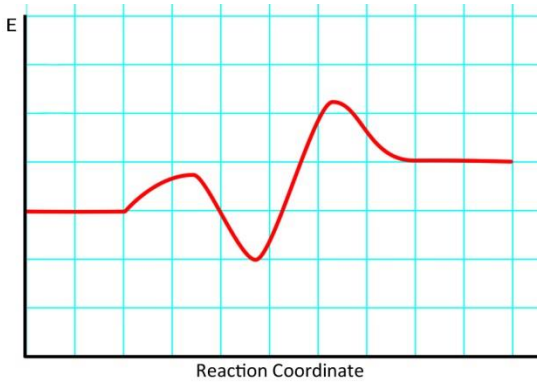
35. Indicate whether each energy diagram below is possible for the catalyzed reaction by marking each as true or false. (6 pts)

a)

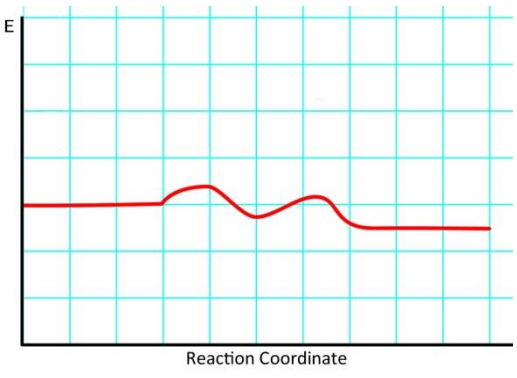
b)

c)

d)



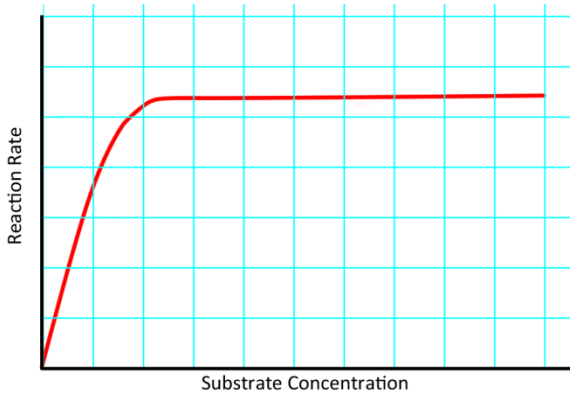
e)



f)

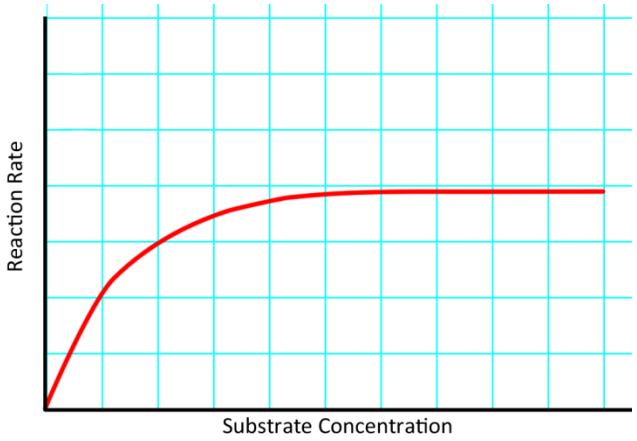
36. Which of the above pathways would be the fastest? Explain. (1 pt)

Eager to find out more about the enzyme, you measure how the catalyzed reaction rate of the enzyme changes with substrate concentration. Your results are shown in the graph below.

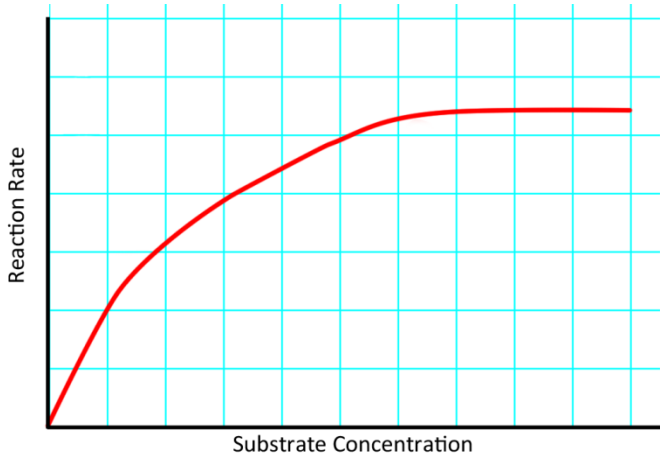


37. (*) You then test the effects of two inhibitors on the enzyme's function. Indicate what type of inhibitor each is based on the results below, and give an explanation. (2 pts each: 4 pts total)

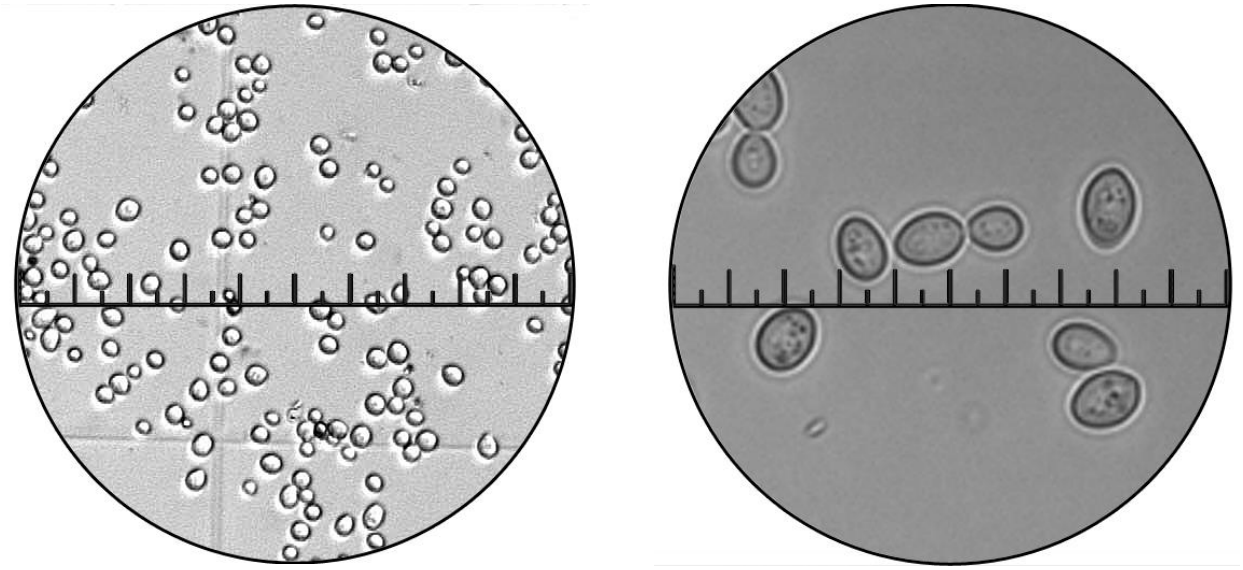
a)



b)



38. Images A and B depict a slide of cells as viewed through a standard light microscope. (5 pts total)



A **B**

Image **A** was viewed through a 10x objective and a 10x eyepiece.
Image **B** was viewed through a 40x objective and a 4x eyepiece.

The diameter of the field of view of image **A** is 200 uM.

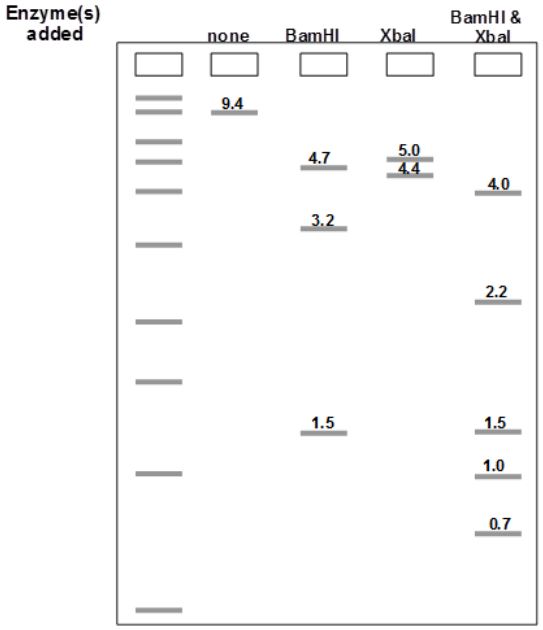
a) Estimate the approximate diameter of a cell in this culture. (1 pt)

b) Calculate the cell density of this culture from image A. Express you answer in terms of cells/mm^2. Please show your work to receive full credit. (3 pts)

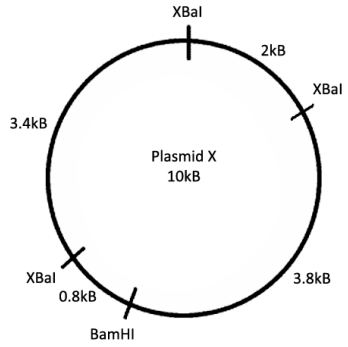
c) What constraint generally limits cells to less than a few hundred microns in diameter? (1 pt)

d) Are the cells on the slide eukaryotic or prokaryotic? (1 pt)

39. (*)You have successfully isolated a plasmid from a bacterial species. You want to characterize the restriction site distribution of this plasmid, so you perform a restriction endonuclease digestion with the enzymes BamHI and XbaI. These two endonucleases specifically cleave DNA at different sites. You treat the plasmid with the following conditions: no restriction enzyme, cutting with BamHI only, cutting with XbaI only, and cutting with both BamHI and XbaI. After running the resulting DNA on a gel and staining with ethidium bromide, you see the bands below. Each fragment is labeled with its length in kilobases. Using this information, answer the questions below about your plasmid. (5pts total)



DNA GEL



EXAMPLE RESTRICTION MAP

a) What is the size of the uncut plasmid? (1 pt)

b) Draw the restriction map of this plasmid for BamHI sites *only*. A restriction map is a diagram of the plasmid with restriction sites marked with their corresponding enzyme and the distances between them labeled in kilobases. An example map is provided above. (2 pts)

c) Repeat part (c) for XbaI sites. (2 pts)

BONUS: Draw the full restriction map of this plasmid with both BamHI and XbaI sites labeled. (2 pts)