For the multiple choice and true/false questions, select the best answer and *mark your response on the pink computer sheet*.

Multiple Choice Questions:

Each of the following 30 questions is worth one mark.

1. I have exam version: (a bonus mark to start you off!)
   a. A
   b. B

2. If some perturbation of an enzyme increases its rate by 10% and the whole pathway is increased by 4%, the enzyme is said to have a flux control coefficient of:
a. 0.1
b. 0.2
c. 0.3
d. 0.4
e. 1.0

3. The standard free energy change of ATP hydrolysis is:
a. 30.5 kJ/mol
b. 0 kJ/mol
c. -30.5 kJ/mol
d. none of the above

4. What is the K'eq for a reaction in which the concentrations of substrates and products in the following reaction that is at equilibrium if the concentrations are A = 2 mol; B = 5 mol; C = 10 mol and D = 10 mol?

A + B <-----> C + D

a. 1000
b. 10
c. 1
d. 0
e. none of the above

5. For the above example in which you calculated the K'eq, if you were to calculate the standard free energy change associated with that reaction, it would be
a. a small positive number (< 10 kJ/mol)
b. a large positive number (> 10 kJ/mol)
c. 0
d. a small negative number (0 to -10 kJ/mol)
e. a large negative number (< -10 kJ/mol)

6. A committing/controlling step in a pathway is one characterized usually by:
a. a large negative free energy change
b. being irreversible
c. being at a branch point in a pathway
d. a and b
e. a, b, and c

7. Iron-sulfur proteins in the electron transport chain participate in one-electron transfers. Which of the electron transport chain complexes contain Iron-sulfur proteins?
a. I, II, III, IV
b. I, II, III
c. II, III, IV
d. III, IV, V
e. none of the above

8. There are two shuttle mechanisms that transport the cytosolic reducing equivalents from NADH into the mitochondria. These are the glycerol 3-phosphate shuttle and the_____.
a. adenine nucleotide transporter
b. phosphate carrier shuttle
c. malate glutamate shuttle
d. malate aspartate shuttle
e. glutamate shuttle

9. The mitochondrial inner membrane has a electrochemical gradient ('protonmotive force') that is maintained at the following mV value to provide a potential energy source to drive ATP synthase:
a. 10 mV
b. 200 mV
c. 500 mV
d. 20 V
e. 100 V

10. The reducing equivalents/electrons during the oxidation of succinate enter the electron transport chain at:
a. complex I
b. complex II
c. complex III
d. complex IV
e. complex V

11. In the electron transport chain, which are the sites of proton pumping (from the matrix to the intermembrane space)?
a. complexes I, II and III
b. complexes I, III and IV
c. complexes I, IV and V
d. complexes II, III and IV
e. complexes II, III and V

12. The glyoxylate cycle functions in plants and some microorganisms to produce glucose from:
a. amino acids
b. starch
c. fatty acids
d. starch and fatty acids
e. none of the above

13. One of the three main controlling steps of the TCA cycle is:
a. succinate dehydrogenase
b. alpha-ketoglutarate dehydrogenase

c. fumarase
d. aconitase
e. malate dehydrogenase

14. Cataplerosis in the TCA cycle occurs when intermediates are 'lost' from the cycle to synthetic reactions in the cell, such as fatty acid synthesis. One very important metabolite in the TCA cycle that is lost is:
a. alpha-ketoglutarate
b. oxaloacetate
c. isocitrate
d. succinate
e. none of the above

15. The reaction in the TCA cycle that produces GTP (ATP) is:
a. citrate synthase
b. aconitase
c. succinyl-CoA synthetase
d. alpha-ketoglutarate dehydrogenase
e. none of the above

16. An iron-sulfur protein in the TCA cycle is:
a. citrate synthase
b. aconitase
c. succinyl-CoA synthetase
d. alpha-ketoglutarate dehydrogenase
e. none of the above

17. Historically many hat makers developed early onset dementia. What was the cause? (Why was the *Mad Hatter* mad?)
a. cyanide toxicity
b. carbon monoxide toxicity
c. dinitrophenol toxicity
d. ethanol toxicity
e. mercury toxicity

18. Pyruvate kinase is regulated in all tissues by levels of ATP, acetyl-CoA, and long-chain fatty acids. In one particular tissue, it is also regulated by its phosphorylation. This tissue is:
a. liver
b. muscle
c. kidney
d. brain
e. adipose

19. Gluconeogenesis is essentially the reverse of glycolysis, except that three enzymatic steps must be bypassed. These steps in glycolysis are catalyzed by the following enzymes:
a. pyruvate kinase; enolase; phosphoglycerate mutase
b. pyruvate kinase; phosphofructokinase; hexokinase
c. pyruvate kinase; phosphoglycerate kinase; hexokinase
d. enolase; phosphoglycerate mutase; phosphoglycerate kinase
e. phophofructokinase phophogglucose isomerise; hexokinase

20. Gluconeogensis occurs in the liver (and to a small extent also in the kidneys). Substrates for gluconeogenesis include all of the following EXCEPT:
a. alanine
b. pyruvate
c. lactate
d. fatty acids
e. tyrosine

21. Which of the following statements about the pentose phosphate pathway is **wrong**?
a. The pentose phosphate pathway is present in most organisms.
b. In most tissues, the proportion of glucose 6-phosphate molecules entering the pentose phosphate pathway is small relative to the proportion of glucose 6-phosphate molecules entering glycolysis.
c. A product of the oxidative phase, ribose 5-phosphate, is used in the synthesis of nucleotides, and the breakdown (catabolism) of fatty acids.
d. CO_2 is released during the oxidative phase.
e. The non-oxidative phase occurs when ribose 5-phosphate is not greatly needed, but there is still a need for NADPH.

22. Which of the following enzyme cofactors is not needed for the activity of pyruvate dehydrogenase?
a. biotin
b. thiamine pyrophosphate
c. lipoate
d. flavin adenine dinucleotide
e. nicotinamide

23. Other monosaccharides than glucose can fuel glycolysis. How does fructose enter glycolysis?
a. an isomerase converts it to glucose, which then is phosphorylated by hexokinase
b. fructose is converted by hexokinase to glucose 6-phosphate (the glycolysis entry point)
c. fructose is converted by hexokinase to fructose 6-phosphate (the glycolysis entry point)
d. fructose is split into one molecule each of glyceraldehyde 3-phosphate and dihydroxyacetone phosphate (the glycolysis entry point)
e. none of the above

24. In the research laboratory, if you were studying the characteristics of glycolytic flux in cultured cells, and you had 'fed' the cells with radioactive glucose, with carbon #6 of the glucose molecules as ^{14}C, which carbon(s) in the glyceraldehyde 3-phosphate molecule would be radiolabeled during glycolysis?
a. 1
b. 2
c. 3
d. all of the carbon molecules
e. none of the carbon molecules

25. The enzyme in glycolysis that catalyzes the splitting of a six carbon substrate to two products each having three carbons is:
a. phosphofructokinase-1
b. phosphoglycerate kinase
c. aldolase
d. enolase
e. phosphoglycerate phosphatase

26. Of the following enzymes in the glycolytic pathway, which reaction is associated with a large negative free energy change?
a. phosphohexose isomerase
b. aldolase
c. glyceraldehyde 3-phophate dehydrogenase
d. phosphoglycerate kinase
e. enolase

27. During alchoholic fermentation in yeast the net production from one molecule of glucose is:
a. 2 ethanol molecules; 2 ATP molecules; 2 NADH molecules
b. 1 ethanol molecule; 2 ATP molecules; 0 NADH molecules
c. 2 lactate molecules; 2 ATP molecules; 2 NADH molecules
d. 2 ethanol molecules; 0 ATP molecules; 2 NADH molecule
e. 2 ethanol molecules; 2 ATP molecules; 0 NADH molecules

28. When the accumulation of a metabolite in a cell directly affects the expression level of mRNA for a pathway enzyme, this is referred to as:
a. post-translational control
b. translational control
c. feed-forward control
d. transcriptional control
e. reciprocal control

29. Researchers can measure the levels of mRNA expression using:
a. metabolomics
b. microarrays
c. genome databases
d. proteomics
e. none of the above

30. Which of the following amounts is closest to the estimated energy equivalent of ATP stored in the adult human body?
a. 0 kcal
b. 100 kcal
c. 500 kcal
d. 1000 kcal
e. 2000 kcal

True or False: **Mark "A" for True, and "B" for False on the pink computer sheet. Each of the following 20 questions is worth ½ mark; therefore 10 marks for this section.**

31) Adult humans do not have any active brown adipose tissue. F *True (A) or False (B)?*

32) The addition of dinitrophenol to a suspension of mitochondria (in the presence of succinate but no ADP) will stimulate mitochondrial oxygen consumption. T *True (A) or False (B)?*

33) When the mitochondrial electron transport chain is inhibited at complex III by antimycin, complex IV is in a reduced state. F *True (A) or False (B)?*

Student Name: _____ **Student Number:**_____

34) Cytochrome c is a small protein located on the outer side of the mitochondrial inner membrane and it transfers electrons from complex III to complex IV (T) *True (A) or False (B)?*

35) Oxaloacetate is one of the metabolites in the TCA cycle that is replenished through anaplerosis. (F) *True (A) or False (B)?*

36) A product of the alpha-ketoglutarate dehydrogenase enzyme is succinyl-CoA. (T) *True (A) or False (B)?*

37) The reaction catalyzed by citrate synthase is highly endergonic. (F) *True (A) or False (B)?*

38) Epinephrine stimulates glycolysis in the liver (F) *True (A) or False (B)?*

39) Glycogen debranching enzyme removes a molecule of non-phosphorylated glucose by breaking the alpha 1-4 linkage. (F) *True (A) or False (B)?*

40) Glycogen phosphorylase cleaves one molecule of glucose, as glucose 6-phosphate, from the non-reducing end of the glycogen molecule. (F) *True (A) or False (B)?*

41) Glycogen provides a rapid source of glucose molecules that can be released from muscle into the blood to help maintain normal blood glucose concentrations. (F) *True (A) or False (B)?*

42) Muscle glycogen stores can be depleted within one hour of vigorous exercise. (T) *True (A) or False (B)?*

43) Some of the gluconeogenic enzymatic reactions occur in the mitochondria as well as in the cytoplasm of liver cells. (T) *True (A) or False (B)?*

44) The enzyme lactase hydrolyzes the disaccharide lactose into the monomers, glucose and galactose. (T) *True (A) or False (B)?*

45) When one molecule of galactose produces two molecules of pyruvate through glycolysis, only one molecule of ATP is produced. (F) *True (A) or False (B)?*

46) 2-phosphoglycerate has a lower standard free energy of hydrolysis than phosphoenolpyruvate (T) *True (A) or False (B)?*

47) The hexokinase reaction is highly endergonic (F) *True (A) or False (B)?*

48) The second law of thermodynamics essentially states that in all natural processes, the entropy of the universe increases. (T) *True (A) or False (B)?*

49) Red blood cells have an obligatory need for glucose (T) *True (A) or False (B)?*

50) After a high carbohydrate meal the circulating levels of the hormone glucagon are high (F) *True (A) or False (B)?*

Student Name: _____ **Student Number:**_____

Fill in the blanks (One mark for each of the blanks; 10 marks in total for this section):

1) The number of protons pumped out of the mitochondrial matrix by the electron transport chain when one molecule of succinate is being oxidized is _____ (1 mark) (6)

2) Draw the structure of pyruvate. (1 mark)

_____

3) Draw the structure of oxaloacetate. (1 mark)

_____

4) Name the molecule that acts in the reciprocal regulation of phosphofructokinase-1 and fructose bisphosphatase-1 activities. _____ (1 mark)

(fructose 2, 6 bisphosphate, or F2,6BP)

5) Name one of the common amino acids that cannot be converted through gluconeogenesis to glucose _____ (1 mark) (either leucine or lysine)

6) The most common human enzyme defect, which can increase the chances of a toxic reaction to antimalarial medications and to divicine is a mutation in the gene for this enzyme _____ (1 mark) (glucose 6-phosphate dehydrogenase; G6PD)

Student Name: _____ **Student Number:**_____

7) Name the enzyme present in liver, but not in muscle, that allows the release of glucose from glycogenolysis into the blood. _____ (1 mark) (glucose 6-phosphatase)

8) In the Cori Cycle, the _____that is exported from the muscle is converted to glucose in liver cells. (1 mark) lactate

9) Name one of the enzymes in glycolysis that catalyzes the second substrate-level phosphorylation step.

_____ (1 mark) (pyruvate kinase)

10) Name the functionally unique isoform of hexokinase that is expressed in the liver.

_____ (1 mark) (glucokinase, or hexokiase IV)

<u>Reminder:</u> Have you filled in the pink computer sheet for multiple choice and true/false questions?