Module Code: BIO00004C

Examination Candidate Number: __________

Desk Number: __________

BSc Degree Examinations 2018-9

Department:
BIOLOGY

Title of Exam:
Molecular Biology and Biochemistry Part II

Time Allowed:
1 hour and 30 minutes

Marking Scheme:
Total marks available for this paper: 50
The marks available for each question are indicated on the paper.

Instructions:
Answer all questions in the spaces provided on the examination paper

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DO NOT TURN OVER THIS PAGE UNTIL INSTRUCTED TO DO SO BY AN INVIGILATOR
Questions 1-20 = 1 mark each (20 marks in total)

1. Complete the sentence. An aldolase catalyses...
A. an aldol condensation
B. the formation of two 3-carbon compounds from a 6-carbon compound
C. the transfer of phosphate groups
D. the first reaction in glycolysis

2. The glycolytic reaction below is what type of reaction and why?

\[
\begin{array}{c}
\text{3-Phosphoglycerate} \\
\text{Phosphoglycerate mutase} \\
\text{2-Phosphoglycerate}
\end{array}
\]

A. An isomerisation reaction because the phosphate group has changed position
B. A hydrolysis reaction because the reaction requires the addition of water
C. A redox reaction because the reaction is coupled to the reduction of NAD\(^+\) to NADH
D. Group transfer because the phosphate group has been transferred from one carbon to another

3. Regarding the conversion of glucose to glucose-6-phosphate via the enzyme hexokinase, which of the following statements is true?
A. The addition of a phosphate group to glucose allows it to bind with membrane transporters to leave the cell.
B. It is a reaction which produces 1 molecule of ATP
C. The binding of glucose to hexokinase causes a conformational change which prevents ATP hydrolysis
D. Hexokinase adds magnesium (Mg\(^{2+}\)) onto ATP to encourage electrophilic attack

4. Which of the following statements regarding glycogen breakdown is incorrect?
A. Adrenaline increases glycogen breakdown
B. Muscle breaks down glycogen using mainly glycogen phosphorylase \(a\) which is most often in the inactive (T) form
C. The products of glycogen breakdown are glucose-1-phosphate and glucose
D. \(\alpha1-6\) bonds are broken using glucosidase via a hydrolysis reaction
5. Sucrose is a disaccharide containing which two monosaccharides?
A. 2 glucose monomers
B. Glucose and fructose
C. Fructose and galactose
D. Glucose and galactose

6. Galactose enters glycolysis via conversion to which glycolytic intermediate?
A. Glucose-6-phosphate
B. Fructose-6-phosphate
C. Fructose-1,6-bisphosphate
D. Glyceraldehyde-3-phosphate

7. Complete the sentence. In beta-oxidation…
A. FADH$_2$ is generated as the only electron carrier
B. the final step (which generates acetyl CoA) is an oxidation reaction
C. carbon atoms are cleaved from the fatty acid chain two at a time
D. unsaturated and saturated fatty acids are processed in the same way

8. Which of the following decreases flux through the TCA cycle?
A. Pyruvate
B. ADP
C. NAD$^+$
D. NADH

9. Concerning the pyruvate dehydrogenase complex, which of the following statements is correct?
A. It consists of 2 subunits
B. It is activated by high acetyl CoA
C. It catalyses a decarboxylation reaction
D. It requires the cofactor FADH$_2$
10. Under times of low oxygen, which of the following enzymes usually produces NAD⁺, rather than NADH?
A. Lactate dehydrogenase
B. Pyruvate dehydrogenase
C. Glyceraldehyde-3-phosphate dehydrogenase
D. Isocitrate dehydrogenase

11. What is the main reason why ketone bodies are used to generate ATP during starvation?
A. Ketone bodies can be used by the brain
B. All other energy stores have been exhausted
C. Ketone bodies generate greater amounts of ATP
D. Ketone bodies produce glucose to maintain blood glucose levels

12. Glycogen is stored in muscle and liver. Why is the liver, not muscle, responsible for regulating blood glucose?
A. The liver contains more glycogen
B. Liver glycogen can be broken down faster
C. The liver is located centrally so is better positioned to regulate blood glucose levels
D. Muscle glycogen is broken down for its own use only

13. Concerning fuel use during exercise, which of the following statements is correct?
A. Phosphocreatine is used initially and can fuel the first 30 minutes of a marathon
B. Fatty acids are the preferred fuel source during short powerful exercises as they generate more ATP
C. Skeletal muscle prefers to use fatty acids to prevent lactate production
D. Athletes try to delay the switch from glucose to fatty acid because fatty acids produce ATP at a slower rate

14. Photorespiration is:
A. a process by which mitochondrial respiration speeds up to keep pace with the supply of reduced carbon during photosynthesis
B. mitochondrial electron transport that only takes place during the light period
C. oxidation of light harvesting complexes
D. a process where plants take up oxygen in the light and release carbon dioxide
15. Light harvesting chlorophylls:
A. are involved in electron transport from chlorophyll to PS1
B. transfer excitation energy to reaction centres using resonance energy transfer
C. mainly convert light energy into heat
D. roughly occur in a 1:1 ratio with chlorophyll reaction centres

16. In plants:
A. carbon is mainly stored as glucose and starch both of which are synthesised in the stroma
B. carbon is mainly stored as sucrose and starch, synthesised in the cytosol and chloroplast
C. carbon is mainly stored as glucose and starch, synthesised in the cytosol and mitochondria
D. carbon is mainly stored as starch, synthesised in peroxisomes

17. In the light, the pH of the chloroplast thylakoid lumen falls from about pH 7.0 to about pH 4.0. This is caused by which of the following processes?
A. Proton pumping by PS1 plus proton pumping by the cytochrome b6/f complex
B. Leakage of H+ out of the lumen via uncouplers plus proton pumping by PS1
C. The splitting of water by the oxygen evolving complex plus proton pumping by the cytochrome b6/f complex
D. The activity of the H+-ATPase plus proton pumping by cytochrome c oxidase

18. If the luminal pH is 4, the formula describing the proton motive force $\text{PMF} = 60 (\text{pH}_o - \text{pH}_i) + \Delta \Psi$, the stromal pH is 7.8 and the membrane electrical potential is +22 mV, then what is the magnitude of the thylakoid PMF?
A. : -250 V
B. : +250 mV
C. : -210 mV
D. : +210 V

19. What is the electron acceptor of Complex II (succinate dehydrogenase) in the mitochondrial electron transport chain?
A. Ubiquinone
B. Plastocyanin
C. Succinate
D. Cytochrome C
20. The redox reactions in the mitochondrial membrane can be summarised in the scheme below

\[ \text{NADH} \rightarrow \frac{1}{2} \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{NAD}^+ \]

If the redox potentials for the separate reactions are:

\[ \frac{1}{2} \text{O}_2 + 2\text{H}^+ + 2\text{e}^- \leftrightarrow \text{H}_2\text{O} \quad E^0 = +0.82 \text{ V} \]
\[ \text{NAD}^+ + \text{H}^+ + 2\text{e}^- \leftrightarrow \text{NADH} \quad E^0 = -0.32 \text{ V} \]

then what is the overall change in free energy?

A. +0.5 V
B. +2.28 V
C. -1.14 V
D. +1.14 V

21.

a) Some muscles rely primarily on fatty acids for energy. In patients with carnitine deficiency, why is weakness of these muscles a common feature? (3 marks)

Carnitine is required for the transport of fatty acids across the inner mitochondrial membrane into the mitochondria (1) where they undergo beta-oxidation (1). Without carnitine, beta-oxidation would cease and ATP production would decrease causing muscle weakness (1).

Most answers attracted some marks for this question. Some incorrectly mistook carnitine for creatine (as in creatine phosphate). Marks were not awarded for stating that carnitine is needed to cross the membrane (needed to state mitochondrial membrane). Some answers also suggested that beta-oxidation takes places outside the mitochondria and acetyl Co-A is transported (via the carnitine shuttle) into the matrix to enter the TCA cycle which is incorrect (beta oxidation also takes place in the mitochondrial matrix).

b) If patients with carnitine deficiency consume a diet rich in medium chain fatty acids, why do the symptoms disappear? (1 mark)

Medium chain fatty acids can enter the mitochondria without the use of carnitine

It appeared that many over-thought this question, so many incorrect answers. Did not accept that less carnitine is used, it had to be stated that carnitine is not required.
22.

a) Explain how phosphofructokinase is allosterically activated during energy depletion. (3 marks)

Phosphofructokinase is activated by allosteric regulators which rise during energy depletion such as ADP (1). When ADP binds to the allosteric site, it causes the amino acid arginine to be repositioned to the catalytic site (1). Arginine is positively charged so attracts the negatively charged substrate, fructose-6-phosphate (1).

Mostly answered reasonably well. Did accept some spelling mistakes/ minor errors in the name of the amino acid/ substrate.

b) How can glycerol generate glucose during times of starvation? (2 marks)

Glycerol can be converted to a glycolytic intermediate, either DHAP or glyceraldehyde-3-phosphate (1) in a process known as gluconeogenesis (1).

Not many answers achieved full marks. Some mistook glycerol for glycogen. Most lost marks for not stating the glycolytic intermediate.

23. Explain why electron flow through Complex II is not associated with ATP synthesis even though electron flow through the other three complexes in the inner mitochondrial membrane does generate ATP. (4 marks)

The reaction catalysed by Complex II involves almost no free energy change between the succinate/fumarate and ubiquinone/ubiquinol redox couples (2 marks). In contrast, there is a significant liberation of free energy as electrons move through each of the other three complexes, enough to pump H+ (2 marks).

Most students had some of this right but often the important fact that there is no change in redox potential (and therefore no release of free energy was missing.

24. The reaction  \( A + B \leftrightarrow C + D \) has a positive change in Standard Gibbs Free Energy (\( \Delta G^\circ \)) of 30kJ/mol. Explain in a few sentences how this reaction can still proceed in a forward direction in the cell. (3 marks)

The reaction can be coupled to another reaction with a \( \Delta G \) that is more negative than -30kJ/mol (1 mark). Alternatively, the ratio of reactants and products can be altered since in non standard conditions the reaction will depend on both \( \Delta G^\circ \) and on the mass action ratio (MAR). (i.e RTln MAR<\(-30kJ/mol\) (2 marks)

Often at least one of these mechanisms was mentioned but disappointingly
large numbers of students think you can change the delta G with an enzyme which is totally impossible!

25.

a) What adaptation have desert plants developed to reduce photorespiration?  
(1 mark)

They use crassulacean acid metabolism (CAM)
Just saying ‘CAM’ earned full credits but, though CAM is a form of C4, C4 is not specific for desert plants so was not credited.

b) In no more than two-three sentences, explain how this adaptation reduces photorespiration and helps plants in hot, dry climates.  
(4 marks)
At higher temperature the partial oxygen pressure rises faster than the partial CO$_2$ pressure which favours oxygenation by Rubisco (2 mark). CAM is a C concentrating mechanism that ensures Rubisco carries out relatively more carboxylation (1 mark) by initially storing PEP-C fixed C as malate (1 mark). This allow CO$_2$ uptake during the night and hence reduces water loss by closing stomata during the day (1 mark).

Most students had a lot of this in their answers although quite a few confused CAM with C4.

26. For the following phospholipid:

![Phospholipid structure]

a) Name the head group  
(1 mark)
Ethanolamine or Phosphoethanolamine (PE)
This question was answered well.

b) Give the alpha-numeric name for the unsaturated fatty acid  
(1 mark)
C$_{18}$:$_2$ $^{\Delta_9,12}$
This question was answered well.

c) Give the alpha-numeric name for the saturated fatty acid  
(1 mark)
C$_{16}$:0
This question was answered well. Some scripts had the correct answers for b) and c) but in the wrong order.
d) There is a much higher concentration of this phospholipid in the inner leaflet of the membrane bilayer than in the outer leaflet. Explain how this asymmetrical distribution is maintained? (2 marks)

It would be energetically unfavourable (0.5 mark) for the hydrophilic head group of PE to pass through the hydrophobic interior of the membrane (0.5 mark). Enzymes known as flippases and floppases (0.5 mark) catalyse this reaction in an ATP-dependent manner (0.5 mark).

This question was answered well.

27. Compare and contrast the structures and functions of chitin and peptidoglycan. (4 marks)

4 marks maximum from the following points:

**Similarities**
Both linear polysaccharides, which have structural roles (1 mark)
Both contain repeating monosaccharides (modified glucose units) linked by beta 1,4 glycosidic linkages (1 mark)

**Differences**
Chitin is a homopolysaccharide while Peptidoglycan is a heteropolysaccharide (1 mark)
Chitin consists of N-acetyl-D-glucosamine (0.5 mark) while Peptidoglycan consists of N-acetyl glucosamine and N-acetyl muramic acid (0.5 mark)
Chitin is found in fungi cell walls and the exoskeleton of arthropods (0.5 mark) while Peptidoglycan is found in bacteria cell walls (0.5 mark)
Peptidoglycan layer also contains cross-linked short chains of amino acids (tetra/penta-peptides) (0.5 mark)

This question was answered well. Some answers did not mention the monosaccharide units or the glycosidic linkages.