A2.1 METABOLIC PATHWAYS
ANSWERS & MARK SCHEMES

QUESTIONSHEET 1

(a) cytoplasm;  

(b) (i) glucose activated by addition of phosphate/by ATP; therefore intermediate B is at a higher energy level;  

(ii) energy taken from B and C; trapped on ATP/NADH;  

(c) enters mitochondrion; converted to acetylcoenzyme A;  

(d) Any three of: NAD/FAD/ receive electrons / H+ are reduced/ coenzymes are reoxidised in the electron transport chain/ generating ATP/ by oxidative phosphorylation;;;  

Total 10

QUESTIONSHEET 2

(a) (i) adenine;  

(ii) ribose;  

(b) (i) intermediate position; means that they can accept or donate (energy rich) phosphate;  

(ii) Any two of: (very) high energy content/ allows rapid/sudden contraction/ since ATP synthesis is relatively slow;;;  

Total 6

QUESTIONSHEET 3

<table>
<thead>
<tr>
<th>Statement</th>
<th>ATP production in Chloroplast</th>
<th>Mitochondrion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrons are excited by photons</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Electrons pass through carriers</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Involves oxidative photophosphorylation</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>ATP produced from ADP and phosphate</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Occurs in day and night</td>
<td>✗</td>
<td>✓</td>
</tr>
</tbody>
</table>

Total 5
**QUESTIONSHEET 4**

(a) \( X \) pyruvate/acetyl coenzyme A; \( Y \) \( CO_2 \); 2

(b) (i) matrix of mitochondrion; 1
(ii) cristae/inner membrane of mitochondria; 1

(c) carriers are alternately reduced and oxidised; 
gain of electrons/hydrogen = reduction/loss of electrons/hydrogen = oxidation; 
linked to ATP synthesis/oxidative phosphorylation; 3

(d) cyanide stops the flow of electrons/blocks the electron transport chain/blocks cytochrome oxidase; 
prevents regeneration of NAD/FAD from NADH/FADH or prevents reoxidation of NADH/FADH/cytochromes; 
thus ATP synthesis is inhibited; max 2

**TOTAL 9**

---

**QUESTIONSHEET 5**

(a) \( X \) ATP; \( Y \) \( CO_2 \)/hydrogen/H; 2

(b) glycolysis in cytoplasm; 
Krebs in matrix of mitochondria; 2

(c) high levels of ATP; 
inhibit conversion of intermediate 1 to intermediate 2; 
prevents excess production of ATP; 3

**TOTAL 7**

---

**QUESTIONSHEET 6**

(a) cytoplasm; 1

(b) provides activation energy/makes glucose more reactive; 1

(c) dehydrogenation/oxidation/redox reaction/(if say reduction must specify \( NAD \rightarrow NADH \)); 1

(d) (i) hydrogen from NADH used to reduce pyruvate to lactate; 2
(ii) hydrogen from NADH used to reduce pyruvate to ethanol;

(e) hydrogen/electrons removed from substrate/intermediate/named intermediate; 
reference to carriers/NAD/FAD; 
passed to successively lower energy levels; 
energy released used to convert ADP into ATP/ phosphorylate ADP; max 3

**TOTAL 8**
### QUESTIONSHEET 7

<table>
<thead>
<tr>
<th>Stage</th>
<th>Site</th>
<th>Oxygen Needed?</th>
<th>What Happens?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycolysis</td>
<td>Cytoplasm;</td>
<td>No;</td>
<td>Glucose is converted to <strong>pyruvic acid</strong>; Hydrogen is removed and is passed to the electron carriers.</td>
</tr>
<tr>
<td>Link Reaction;</td>
<td>Matrix of Mitochondria;</td>
<td>Yes;</td>
<td>Pyruvate enters mitochondrion, is decarboxylated, dehydrogenated and combines with coenzyme A to give acetyl coenzyme A. The hydrogen which is removed is passed to the electron carriers.</td>
</tr>
<tr>
<td>Kreb’s Cycle;</td>
<td>Matrix of Mitochondria;</td>
<td>Yes;</td>
<td>A cyclical series of reactions during which hydrogen is passed to the electron carriers, carbon dioxide is removed and a starting reactant is regenerated.</td>
</tr>
<tr>
<td>Electron Transfer Class</td>
<td>Crista/Inner Membrane of Mitochondria;</td>
<td>Yes</td>
<td>The hydrogen from the respiratory reactions is split to release electrons. These pass through carriers and generate <strong>ATP</strong>. The hydrogen reforms and is combined with oxygen to release water.</td>
</tr>
</tbody>
</table>

**TOTAL 9**

### QUESTIONSHEET 8

(a) Any three of:
- glucose phosphorylated/activated/
- using ATP/
- split into 3C/triose phosphate/
- oxidation/dehydrogenation of trioses yields pyruvate;;;

(b) (i) cytoplasm;

(ii) matrix of mitochondria;

(c) Any three of:
- ATP binds to enzyme/isocitrate dehydrogenase/
- at a site other than the active site/
- this changes the shape of the enzyme/active site/
- therefore substrate cannot attach and process slowed/
- this happens when too much ATP has been made;;;

(d) Any three of:
- pyruvate decarboxylated to ethanal/
- producing carbon dioxide/
- ethanal converted/reduced to ethanol/
- enabling NADH to be oxidised to NAD;;;

**TOTAL 12**
**QUESTIONSHEET 9**

(a) Any three of:
- overwatering leads to anaerobic condition/
- anaerobic conditions inhibit electron transport chain/
- thus pyruvic acid/pyruvate has been converted into ethanol/
- to enable NADH to be reoxidised to NAD;

(b) Any two of:
- acetyl coenzyme A can be formed from other substrates/
- from breakdown of fats/
- from deamination of amino acids;;

(c) Any four of:
- oxygen supply to muscles is inadequate during severe exercise/
- thus electron transport system inhibited/
- thus NADH cannot be reoxidised/
- pyruvic acid converted to lactic acid/
- changing NADH back to NAD;;;

**TOTAL 9**

**QUESTIONSHEET 10**

(a) (i) lactate/lactic acid;
- carbon dioxide;
- electrons/hydrogen;[reject H2]

(b) (i) adds phosphate to ADP to produce ATP;
- remove hydrogen from substrates/oxidise substrates/pass hydrogen to acceptors;

(c) without oxygen there is no final acceptor for electrons/hydrogen from electron transport chain;
- hence no regeneration /reoxidation of coenzymes;
- Krebs cycle stops;
- electron transport chain and Krebs cycle provide most of the ATP;

**TOTAL 9**

**QUESTIONSHEET 11**

(a) (i) organic molecules necessary for enzyme function;
- not permanently attached to the enzyme;
- involved in transfer of hydrogen/electrons/acetate groups/energy/any other correct example;

(ii) similar to coenzyme but tightly bound to one specific enzyme;

(b) vitamin B complex/nicotinic acid/riboflavin is required for synthesis of NAD/FAD;
- pantothenic acid/coenzyme A required to produce acetyl CoA from pyruvate;
- less acetyl CoA means less substrate for the Krebs cycle;
- NAD/FAD are hydrogen acceptors in respiration;
- if deficient electron transport chain may be impaired so less ATP produced;

**TOTAL 7**
A2.1

METABOLIC PATHWAYS

QUESTIONSHEET 12

(a) glycolysis;  

(b) X ATP;  
    Y ADP;  

(c) (i) facilitated diffusion/active transport;  
    (ii) cytoplasm;  

(d) (i) to make glucose reactive/phosphorylation gives energy of activation/keeps glucose inside cell/there are no carriers for glucose-6-phosphate in the cell membrane/keeps concentration of free glucose inside cell low so maintains concentration gradient;  
    (ii) they lack mitochondria;  
    therefore rely on glycolysis to provide energy;

TOTAL  8

QUESTIONSHEET 13

(a) (i) liver;  
    (ii) deamination/transdeamination;  
    (iii) limited solubility of ammonia in water means too much water would be lost when excreting the amounts of ammonia produced; mammals being land animals cannot risk losing too much water;  
    [allow 1 mark only if say ‘would incur too much water loss]  

(b) (i) liver;  
    (ii) (by-product of) respiration;  
    (iii) because ammonia and carbon dioxide are attached to it to assemble urea;  
    it is reformed when the urea is split off it;  
    (iv) hydrolysis;  
    (v) urea is more soluble in water than ammonia;  
    thus involves less water loss in urine which is advantageous to a land animal/no need to carry large volumes of urine around;

TOTAL  11
QUESTIONSHEET 14

(a) diffusion is the movement of molecules down a concentration gradient;
    energy is released as molecules diffuse;
    active transport is the movement against a concentration gradient;
    involves the expenditure of energy/ATP;
    involves the use of carriers;  
    max 4

(b) (i) oxidative phosphorylation;  
    max 1

(ii) proton pumps;
    because they move hydrogen ions which are protons;  
    max 2

(iii) enables protons/hydrogen ions to diffuse back across the membrane;
    ref to proton motive force/surplus of positive ions on inside of membrane;
    movement of protons back releases energy;
    which is harnessed by enzyme to convert ADP + P to ATP;  
    max 3

TOTAL 10

QUESTIONSHEET 15

(a) the volume of carbon dioxide evolved;
    divided by the volume of oxygen absorbed;
    (or allow, moles/molecules of carbon dioxide evolved;
    divided by moles/molecules of oxygen used);  
    max 2

(b) (i) $RQ = \frac{114}{160} = 0.7125$ (allow 0.71);  
    max 2

(ii) $RQ$ when respiring only carbohydrate would be 1.0;
    because volume CO$_2$ released (6CO$_2$) equals volume of O$_2$ used (6O$_2$);
    $RQ$ when respiring only fat is 0.7;
    humans respire both carbohydrate and fat at the same time;  
    max 3

(c) (i) there would be no movement of the fluid in the manometer;  
    max 1

(ii) use water bath/incubator to keep temperature constant thus avoiding gas volume changes;
    stated suitable temperature (15 – 25°C);
    have tap open and allow time (at least 10 minutes) to equilibrate;
    close tap and allow to work for suitable time (at least 30 minutes);  
    max 3

(iii) glycolysis, Krebs cycle, respiratory chain/electron transport chain;  
    max 1

TOTAL 13
QUESTIONSHEET 16

(a) (i) glucose must be activated/given energy before it can be metabolised/made more reactive; phosphorylating with the energy rich bond of ATP gives glucose the extra energy needed; 2

(ii) changing to a different structural molecular shape whilst retaining the same empirical/molecular formula; 1

(iii) enolase is substrate specific for fructose/cannot accept glucose as a substrate; 1

(iv) to produce reduced NAD/NADH/NADH₂; which can be used/reoxidised in the respiratory chain/electron transport chain; so that ATP is synthesized; max 2

(b) (i) yeast respires/produces carbon dioxide and water, using the normal aerobic pathway when oxygen is available; when oxygen is missing NADH₂ has to be reoxidised without the use of the electron transport chain; this is done by decarboxylating pyruvic acid/removing CO₂ from pyruvic acid, to form ethanal; this is hydrogenated/reduced to ethanol using NADH₂ which is reoxidised to NAD; 4

(ii) Lactobacilli are prokaryotic and so have no mitochondria/respiratory chain is not highly organised; thus NADH₂ is reoxidised by hydrogenating/reducing pyruvic acid to lactic acid; 2

(iii) yoghurt manufacture; 1

(b) Lactobacilli/bacteria in the mouth/buccal cavity produce lactic acid; this can cause decay/erode enamel of teeth; if enolase is inhibited then the bacteria cannot produce the lactic acid; (credit any reference to fluoride being incorporated into the enamel, thus hardening it) max 2

TOTAL 15

QUESTIONSHEET 17

(a) (i) it is the volume of carbon dioxide /number of carbon dioxide molecules or moles liberated; divided by the volume of oxygen/number of oxygen molecules or moles used; 2

(ii) because they do not respire only carbohydrate or only fat but a mixture of them; protein is not usually respired in large amounts except in starvation; 2

(iii) when they are using the carbon dioxide for something else and so not releasing it; for example, in photosynthesising plants; 2

(b) (i) barley seeds are respiring mainly starch and so have a RQ approaching 1.0; castor oil seeds store oil and so are respiring fat (oil) and so have a RQ approaching 0.7; barley seeds contain little lipid whereas castor oil seeds contain little starch; max 2

(ii) photosynthetic leaves/cotyledons/coleoptiles will have formed; thus starch synthesis occurs and both sets of seeds can now respire carbohydrate; initial starch content/oil content probably used up; max 2

TOTAL 10
QUESTIONSHEET 18

(a) (i) amino acids cannot be stored since their amine groups are toxic; deamination removes the amine groups of surplus amino acids for excretion;  
(ii) in the liver/hepatic cells;  

(b) (i) it is respiratory since NADH is produced by dehydrogenation (and this can be used to generate ATP); it also generates pyruvic acid which can be used in the Krebs cycle (to generate more ATP); it is excretory since it removes toxic amine groups as ammonia (for excretion);  
(ii) pyruvic acid forms acetyl coenzyme A in the link reaction; which is further metabolised in the Krebs cycle;  
NADH is reoxidised to NAD in the respiratory chain/electron transport chain; resulting in ATP synthesis;  
ammonia enters the ornithine cycle to be assembled into urea; which is transported by the blood to the kidneys for excretion;  

TOTAL 12

QUESTIONSHEET 19

phosphorylation/adding phosphate; ATP/adenosine triphosphate; fructose diphosphate; triose phosphate; NADH; glycolysis; cytoplasm; mitochondrion; inner; respiratory chain/electron transport chain; three; protons/hydrogen ions; oxygen; cytochrome; link; Krebs cycle;  

TOTAL 16

QUESTIONSHEET 20

(a) false;  
body proteins are continually recycled/broken down and replaced;  
amino acids formed are toxic;  
so if not immediately used for protein reassembly must be deaminated;  
surplus dietary amino acids are also deaminated;  
deamination generates NADH (for ATP synthesis) and so is a respiratory process;  

max 5

(a) true;  
camel will be short of water (in desert);  
water is a byproduct of respiration;  
respiration of 1 gramme of fat yields more water than respiration of 1 gramme of carbohydrate;  
almost twice as much water yielded from fat;  

max 4

(b) false;  
if oxygen is available yeast respires by the aerobic pathway;  
when oxygen is not available NADH must be reoxidised in an alternative way;  
by converting pyruvic acid to ethanol;  

max 3

TOTAL 12