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ANSWER BOOK

The liver: detoxification, deamination and the making of urea

Hormonal communication, plant responses and homeostasis · Unit B15

OCR A 5.1.2 · Edexcel B 9.9 ii · CAIE 14.1

15 questions · 52 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 LD-Q7

B1 excretion is the removal from the body of the waste products of metabolism, such as carbon dioxide and urea. **B1** faeces consist of undigested food, bacteria and dead gut lining, which have never taken part in the body's own reactions, so passing them out is egestion. [2]

A2 LD-Q15

B1 carbon dioxide is excreted at the alveoli of the lungs. **B1** excess carbon dioxide forms carbonic acid in the blood, so the blood pH falls. [2]

SECTION B · Standard, 3 to 5 marks

B1 LD-Q1

B1 deamination in a hepatocyte removes the amino group, which leaves as ammonia, and the remainder of the molecule is a keto acid that is respired or converted to glucose or fat. **B1** in the mitochondrion, the ammonia combines with carbon dioxide and joins ornithine to form citrulline. **B1** in the cytoplasm, the citrulline takes up a second ammonia and becomes arginine. **B1** also in the cytoplasm, the arginine is hydrolysed to urea and ornithine, so the ornithine is available to start the cycle again. **A1** overall two molecules of ammonia and one of carbon dioxide give one molecule of urea, which diffuses into the blood and is excreted by the kidney. [5]

B2 LD-Q2

B1 a lobule is a roughly hexagonal block of hepatocytes with a central vein running down its axis. **B1** at each corner sit branches of the hepatic artery and of the hepatic portal vein, together with a bile ductule. **B1** blood from both vessels flows inwards from the corners along wide leaky capillaries called sinusoids, mixing as it goes, and drains into the central vein. **A1** bile is secreted by the hepatocytes into bile canaliculi running between them and travels outwards to the ductules at the corners, so blood and bile move in opposite directions. [4]

B3 LD-Q3

B1 ethanol is oxidised by ethanol dehydrogenase to ethanal. **B1** ethanal is oxidised by ethanal dehydrogenase to ethanoate, which is converted to acetyl coenzyme A and fed into respiration. **B1** both steps pass hydrogen to NAD, so reduced NAD accumulates in the hepatocytes. **A1** a cell with plenty of reduced NAD synthesises fatty acids rather than oxidising them, so fat builds up in the hepatocytes, and sustained damage leads on to cirrhosis as scar tissue replaces the cells. [4]

B4 LD-Q8

B1 Kupffer cells are macrophages fixed in place along the sinusoids of the liver. **B1** they engulf bacteria arriving from the gut in the blood, and they break down worn-out red blood cells. **B1** the haem group from those red blood cells is converted into bile pigments. **A1** the bile pigments leave the liver in the bile, pass into the gut and colour the faeces, which is why faeces contain some body-derived material as well as undigested food. [4]

B5 LD-Q9

B1 a swallowed drug is absorbed from the gut into the blood of the hepatic portal vein. **B1** the hepatic portal vein carries that blood, and everything dissolved in it, directly to the liver before it reaches any other tissue. **B1** hepatocytes detoxify a wide range of substances using enzymes such as those of the cytochrome P450 group, so a significant fraction of the drug can be broken down on this first pass through the liver. **A1** an injected drug enters the general circulation directly and is diluted throughout the whole blood volume before any of it reaches the liver, so a much higher fraction of the same dose reaches the rest of the body intact. [4]

B6 LD-Q10

B1 in cirrhosis, many working hepatocytes have been replaced by fibrous scar tissue, so there is less of the enzyme available to detoxify the drug. **B1** the same dose is therefore broken down more slowly than in a person with a healthy liver. **B1** a lower dose is prescribed so that the concentration of active drug reaching the blood stays within a safe range despite the slower removal. **A1** if the normal dose were given repeatedly, the drug would not be cleared between doses, so its concentration in the blood would keep rising with each dose and could reach a toxic level even though each individual dose was the standard one. [4]

B7 LD-Q11

B1 uric acid is almost insoluble in water and can be excreted as a semi-solid paste, using very little water compared with a liquid solution of urea. **B1** a shelled egg is a sealed container: nothing can be added to it once it is laid, so the developing embryo inside cannot obtain more water to dilute a soluble waste product. **B1** if the embryo excreted urea instead, being soluble, it would accumulate as a solution inside the shell and its concentration would keep rising as development continued. **A1** because uric acid is insoluble, it can be stored inside the shell as a solid without raising the water potential of the fluid around the embryo, so development can continue without the embryo either poisoning itself or running out of water. [4]

B8 LD-Q12 [4]

B1 carbon dioxide is produced by respiration in essentially every living cell, whereas urea is produced specifically in the liver, from the deamination of surplus amino acids. **B1** carbon dioxide needs no processing before excretion, being carried in the blood mostly as hydrogencarbonate ions, whereas the more toxic ammonia from deamination is processed in the liver into far safer urea first. **B1** carbon dioxide leaves the body at the lungs, across the alveolar epithelium, whereas urea leaves the body at the kidney, filtered out at the renal capsule and concentrated in the urine. **A1** both are true excretory products under the same definition, since both are waste products of the body's own metabolism, even though one requires a dedicated chemical conversion by an organ before it can be safely excreted and the other does not.

B9 LD-Q4 [3]

B1 the hepatic artery, carrying oxygenated blood from the aorta. **B1** the hepatic portal vein, carrying deoxygenated blood from the gut that is rich in absorbed food and in anything else taken in with a meal. **B1** the hepatic vein, which carries blood away to the inferior vena cava.

B10 LD-Q5 [3]

B1 ammonia is extremely soluble and very toxic, particularly to nervous tissue, so only a very low concentration can be tolerated in the blood. **B1** excreting it would therefore require a large volume of water, which a fish surrounded by water can lose freely but a land mammal cannot replace. **A1** urea is far less toxic and still soluble, so it can be carried in the blood at a much higher concentration and concentrated further in the urine, and the ATP spent on the ornithine cycle is what makes that saving possible.

B11 LD-Q6 [3]

B1 urea is made in the liver, so with fewer working hepatocytes there are fewer ornithine cycles running and less urea is produced. **B1** deamination continues and ammonia also arrives from gut bacteria along the hepatic portal vein, but too little of the cycle remains to convert it, so ammonia accumulates. **A1** blood urea is usually read as a measure of kidney excretion on the assumption that production is steady; here production has fallen, so a low value says nothing reassuring about the kidneys.

B12 LD-Q13 [3]

B1 catalase catalyses the decomposition of hydrogen peroxide into water and oxygen. **B1** hydrogen peroxide is toxic and is produced continuously as a by-product of the many metabolic reactions, including detoxification reactions, taking place in a hepatocyte. **A1** because hepatocytes carry out so much metabolism, they generate hydrogen peroxide faster than most cells, so they need a correspondingly large amount of catalase to break it down before it can damage the cell.

B13
LD-Q14

B1 the surplus amino acids cannot be stored, since there is no store for amino acids as glycogen stores glucose, so they are deaminated in the liver: the amino group leaves as ammonia and the keto acid remaining is respired or converted to glucose or fat. **B1** the ammonia produced enters the ornithine cycle and is converted into urea, so more surplus protein being deaminated means more urea being produced per day than in someone eating a normal amount of protein. **A1** because the extra urea is made continuously while the high-protein diet continues, and the kidney takes time to filter and excrete each batch, the athlete's blood urea settles at a higher steady level than someone eating less protein, even with normally functioning kidneys. [3]

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