Model Answers: Hard

1a

(a) The structure of the nephron and its associated blood vessels are adapted to the process of ultrafiltration by...

Any **eight** of the following:

- The capillary endothelium...; [1 mark]
- ...has many gaps/pores/fenestrations; [1 mark]
- The afferent arteriole is wider than the efferent arteriole; [1 mark]
- (This maintains) high blood/hydrostatic pressure in glomerulus; [1 mark]
- Fluid is forced out of the glomerulus / into the Bowman's capsule (due to the high pressure); [1 mark]
- (The walls of the glomerulus consist of cells known as) podocytes; [1 mark]
- (Podocytes are cells that) have interlocking / finger-like processes/extensions...; [1 mark]
- ...that form filtration slits/pores; [1 mark]
- (Between the capillary endothelium and the podocytes is the) basement membrane; [1 mark]
- (The basement membrane is a mesh of) collagen / glycoprotein (fibres); [1 mark]
- (The basement membrane) acts as the (main) selective barrier/filter; [1 mark]
- Large proteins/molecules do not pass through; [1 mark]
- Red/white blood cells do not pass through; [1 mark]
- Water / solutes/ions pass through; [1 mark]

Ignore *'basal' membrane for marking point 9.*

Reject *large 'substances' for marking point 12.*

[Total: 8 marks]

The question asks you to explain how the structure of the nephron and surrounding blood vessels are **adapted for ultrafiltration**, so general description of kidney structure or of unrelated parts of the nephron such as the loop of Henle will not be credited.

The process of ultrafiltration is **not** an example of diffusion but comes about as a result of the **high hydrostatic pressure** that results from the wider afferent and narrower efferent arterioles.

When describing the podocytes it is important that you describe their structure correctly; marks will not be awarded for statements such as

'podocytes *are* finger-like processes' as this is not a correct statement; you should instead say that 'podocytes are cells that **have** finger-like processes'.

1b

(b) The effects of insulin on its main target tissues and the ways in which this leads to changes in blood glucose concentration are...

Any **seven** of the following:

- (**Two** examples from =) target tissues (of insulin) are liver / muscle / adipose; [1 mark]
- (Insulin causes) an increase in glucose uptake (by the cells of the target tissues); [1 mark]
- (Insulin) increases the permeability of cells to glucose; [1 mark]
- (This is achieved because) more glucose transporter/GLUT (4) proteins (are added to membranes of target tissue cells); [1 mark]
- (This occurs when) vesicles (containing GLUT proteins) fuse with cell surface membrane; [1 mark]
- (Insulin) stimulates glycogen synthesis/glycogenesis; [1 mark]
- (Insulin) activates (the enzyme) glucokinase / glycogen synthase; [1 mark]
- Lipid/triglyceride/fatty acid synthesis is stimulated; [1 mark]
- There is an increase in respiration (of glucose); [1 mark]
- (So) more (facilitated) diffusion of glucose into (liver) cells; [1 mark]
- There is a decrease in glycogenolysis / lipolysis / gluconeogenesis; [1 mark]
- (All of the above work together to) decreases blood glucose concentration; [1 mark]

[Total: 7 marks]

Insulin does not convert glucose to glycogen directly, instead it **activates enzymes** which eventually enable this reaction to occur.

Note that insulin is not solely responsible for making process like respiration or diffusion of glucose into a target cell occur (these process will be occurring anyway!); the role of insulin is to **increase the rate** at which these processes take place.

2a

(a) Insulin affects body cells in the following ways...

Any **three** of the following:

- (Insulin) binds to a receptor on the cell surface membranes of target/liver/muscle/fat/adipose cells; [1 mark]

- Vesicles containing GLUT4/glucose transporter proteins move to/fuse with the cell surface membrane / the number of GLUT4/glucose transporter proteins in the cell surface membrane increases; [1 mark]
- Activates enzymes that convert glucose to glycogen / catalyse glycogenesis; [1 mark]
- Increases the rate of respiration (so causing glucose to be used up faster); [1 mark]
- Activates enzymes that phosphorylate glucose, preventing it from leaving the cells; [1 mark]

[Total: 3 marks]

2b

(b) Evaluative points relating to this conclusion include...

In support of the conclusion

A maximum of **two** of the following:

- The higher the dose of metformin the more the blood glucose levels are reduced / the lower the blood glucose level; [1 mark]
- There is a (statistically) significant difference between the control group and the metformin groups / metformin has a (statistically) significant effect on blood glucose levels (this can be seen because the standard deviations do not overlap); [1 mark]
- The mice fasted for 12 hours beforehand so the results would not have been affected by previous meals; [1 mark]
- Mice are mammals so the drug is likely to have a similar effect in humans; [1 mark]
- The mice were given an equivalent dose of drug for their body mass; [1 mark]

Against the conclusion

A maximum of **two** of the following:

- Metformin could act differently in humans / the results cannot be directly applied to humans; [1 mark]
- The sample size was small so may not be representative of all mice; [1 mark]
- The experiment would need to be repeated with the same results / no repeats have been carried out; [1 mark]

[Total: 3 marks]

When evaluating conclusions, be sure to take both sides of the argument into account. You should look at the results from which a conclusion has been made and consider whether they provide support, and you should also think more generally about the experimental method used; consider control variables, the use of experimental controls, and whether the results are representative enough to be valid.

2c

(c) Metformin reduces the impact of non-functioning insulin by...

Any **three** of the following:

- Cyclic AMP/cAMP cannot bind to protein kinase A / less cAMP binds to protein kinase A; [1 mark]
- No enzyme cascade is initiated / there is less amplification of the signal (from cAMP); [1 mark]
- No/less activation of glycogen phosphorylase / enzymes that break down/hydrolyse glycogen / carry out/catalyse glycogenolysis; [1 mark]
- Concentration of glucose inside the cell does not increase / less glucose is released into the blood (reducing blood glucose levels); [1 mark]

[Total: 3 marks]

Metformin works by reducing the function of the enzymes that normally work to increase blood glucose. By reducing levels of cAMP inside the cell, the series of reactions that lead to activation of glycogen breakdown do not take place, and glucose remains locked up in the body's glycogen stores.

2d

(d) (i) Urine test strips for glucose do not show the presence of other sugars because...

- The glucose oxidase enzyme (on the strip) is specific/complementary to glucose / sugars other than glucose do not fit into the active site of glucose oxidase; [1 mark]

(d) (ii) Glucose is present in the urine of diabetic individuals because...

- Not all glucose is selectively reabsorbed / absorbed during selective reabsorption **OR** some glucose remains in the filtrate/urine after selective reabsorption (in the proximal convoluted tubule); [1 mark]

[Total: 2 marks]

Enzymes are specific to their substrates; in this case glucose oxidase is specific to glucose. This means that other sugars will not be complementary to its active site and will not bind to it.

In the kidneys of non-diabetic patients it is usual for all of the glucose to be reabsorbed in the proximal convoluted tubule of the kidney nephron, but the blood glucose levels in diabetic patients are high enough that some glucose remains in the filtrate after selective reabsorption

3a

(a) (i) Region **1** of the nephron is...

- Proximal convoluted tubule; [1 mark]

(a) (ii) The reason this can be identified is...

- Most substances are reabsorbed here / all of the glucose is reabsorbed here; [1 mark]

Accept *references to this being the first section of the nephron after the Bowman's capsule.*

[Total: 2 marks]

The percentage of the nutrients (in comparison to the nutrients that originally entered the filtrate) are all decreasing through region **1**, showing that they are all leaving the filtrate. This would happen during selective reabsorption, and as we know that most substances (and all glucose) are reabsorbed in the proximal convoluted tubule, this suggests that region **1** is located here.

3b

(b) The active pumping of sodium ions into the medulla accounts for the reabsorption of water from region **2** because...

- Sodium lowers the water potential of the (cells of the) medulla; [1 mark]
- Water moves out of region **2** by osmosis / down a water potential gradient; [1 mark]

[Total: 2 marks]

You are not expected to know the details of water reabsorption from the loop of Henle (region **2**), but you have been given enough information here to suggest what is happening. The pumping of sodium ions into the medulla surrounding region **2** lowers its water potential, causing water to leave region **2** by osmosis; this can be seen in the downward curve for water in the first half of region **2** in Fig. 1.

3c

(c) (i) Two features visible in Fig. 2 that aid the process of reabsorption are...

- Many mitochondria; [1 mark]
- Microvilli; [1 mark]

(c) (ii) These features aid reabsorption by...

- (Mitochondria) release energy for active transport / to power (Na^+/K^+) pump/transporter proteins; [1 mark]
- (Microvilli) increase the surface area (for reabsorption of substances); [1 mark]

***Reject** references to production of energy*

[Total: 4 marks]

3d

(d) The role of Na^+/K^+ transporter proteins in the reabsorption of nutrients is...

Any **three** of the following:

- Pumping sodium out of the (epithelial) cell into the blood/capillary; [1 mark]
- Creating a sodium gradient between the (lumen of the) nephron/tubule and the (epithelial) cell; [1 mark]
- Sodium diffuses / moves down its concentration gradient out of the nephron/tubule into the cell; [1 mark]
- Sodium moves (out of the nephron) by the action of a cotransporter protein (along with glucose/amino acids); [1 mark]

[Total: 3 marks]

The sodium-potassium pumps are responsible for creating the gradient that allows the cotransport of sodium and another molecule out of the nephron and into the epithelial cells. The pumps actively transport sodium into the blood, creating a gradient that allows sodium to diffuse via cotransporter proteins into the cell from the nephron. This movement of sodium down its concentration gradient enables the cotransporter protein to carry another molecule (either glucose or amino acid) against its concentration gradient.