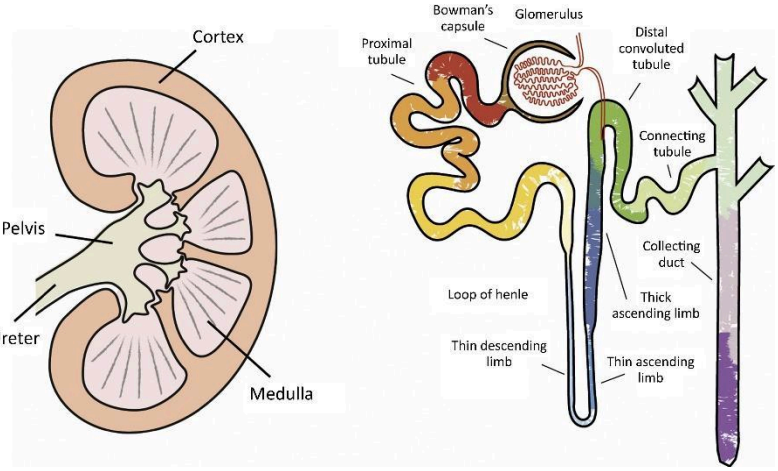
# IB Biology

# Revision

## Topic 11.3 – The Kidney and Osmoregulation




**Name:**

**Teacher:** Mr Trent

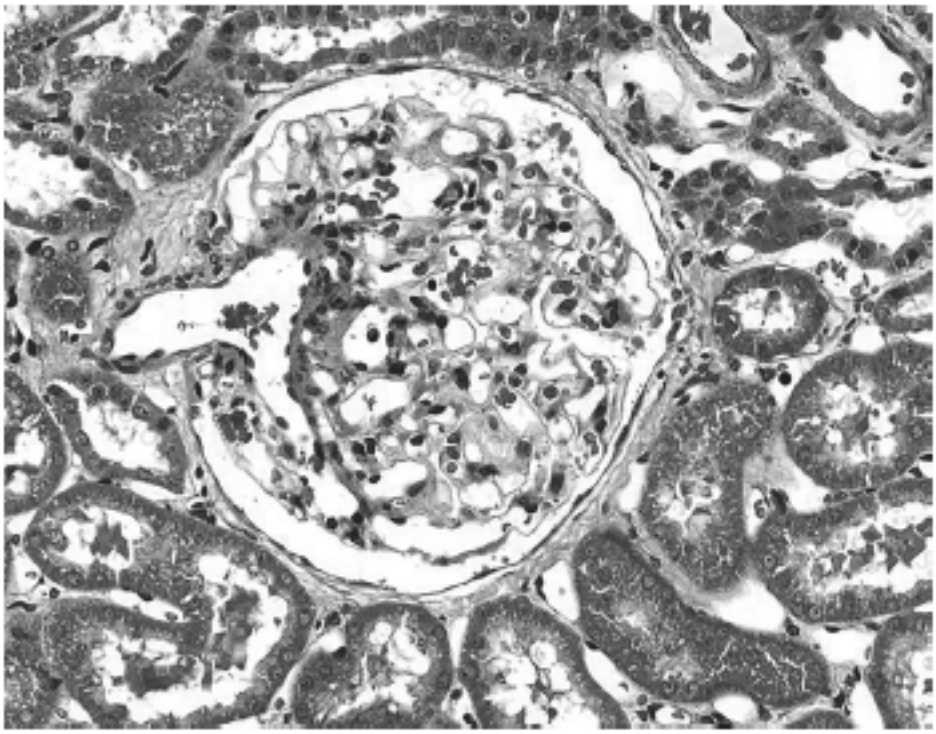
**1.** *[1 mark]*

Glucose moves from the filtrate in the nephron into the bloodstream during normal kidney function. Which location and method describe this movement of glucose?

| | Location | Method |
|---|---|---|
| A. | Glomerulus | Ultrafiltration |
| B. | Proximal convoluted tubule | Ultrafiltration |
| C. | Glomerulus | Active transport |
| D. | Proximal convoluted tubule | Active transport |

**2.** *[1 mark]*

The micrograph shows a glomerulus and Bowman's capsule, where ultrafiltration takes place in the kidney.



What facilitates the formation of glomerular filtrate?

A. Many fenestrations in walls of capillaries in the glomerulus

B. High pressure in the Bowman's capsule

C. ADH secreted by the pituitary gland

D. Osmosis caused by a high concentration of urea in the blood

**3.** *[1 mark]*

What sequence shows the route taken by nitrogenous wastes in insects from their production in body cells to their removal from the insect's body?

A. Hemolymph → Malpighian tubule → hindgut → rectum

B. Hindgut → hemolymph → kidney tubule → bladder

C. Malpighian corpuscle → nephron → ureter → bladder

D. Neonicotinoid → rectum → antagonistic muscles → anus

**4.** *[1 mark]*

Damselflies are flying insects. They lay eggs that hatch into larval forms that are aquatic. Adults excrete uric acid while the larval forms excrete ammonia. What is a possible explanation of this?

A. Uric acid can be excreted in a more concentrated form than ammonia.

B. Ammonia is less toxic than uric acid.

C. Uric acid requires more water for excretion than ammonia.

D. Only adult forms can produce uric acid.

**5.** *[1 mark]*

What is the function of the loop of Henle?

A. To reabsorb salt

B. To maintain a hypertonic solution in the medulla

C. To transport liquid from the collecting ducts to the convoluted tubules

D. To reabsorb glucose

**6.** *[1 mark]*

The presence of proteins such as albumin in a urine sample indicates kidney damage. Where in the kidney would the damage exist?

A. Renal artery

B. Cortex

C. Medulla

D. Pelvis

**7.** *[1 mark]*

What is the effect of ADH on the kidney?

A. It stimulates ultrafiltration in the Bowman's capsule.

B. It inhibits reabsorption of water in the proximal convoluted tubules.

C. It inhibits reabsorption of ions in the loop of Henle.

D. It stimulates reabsorption of water in the collecting duct.

**8.** *[1 mark]*

Which structure found in eukaryotes has a single membrane?

A. Nucleus

B. Lysosome

C. Chloroplast

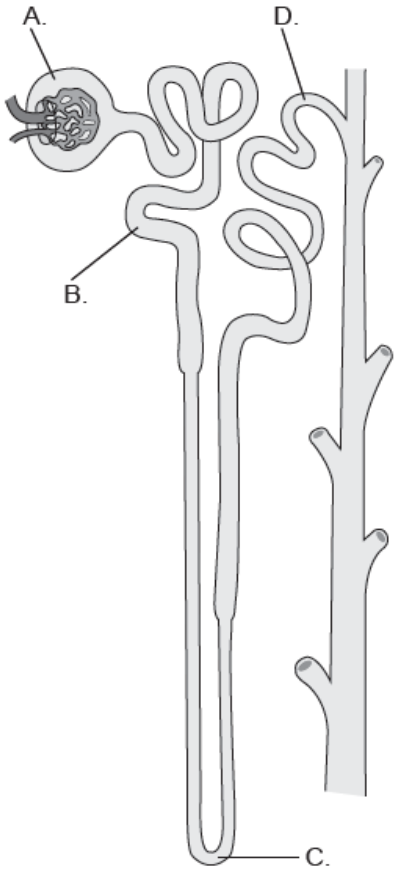
D. Mitochondrion

**9.** *[1 mark]*

The table shows solute concentrations in normal blood plasma and the fluid in one section of the nephron.

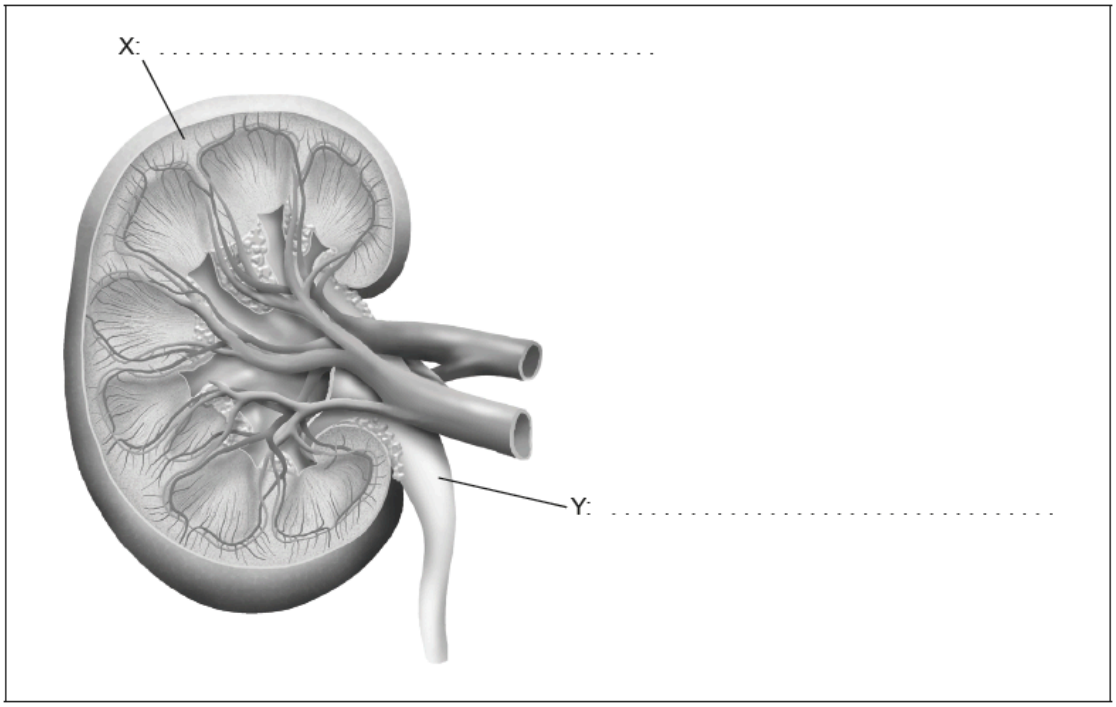
| Solutes | Plasma | Fluid inside the nephron |
|---|---|---|
| $Cl^-$ ions | 110 mol $dm^{-3}$ | 110 mol $dm^{-3}$ |
| Glucose | 5 mol $dm^{-3}$ | 5 mol $dm^{-3}$ |
| Urea | 5 mol $dm^{-3}$ | 5 mol $dm^{-3}$ |
| Proteins | 750 mg $dm^{-3}$ | 3–4 mg $dm^{-3}$ |

In which section of the nephron would you expect to fi nd these concentrations?



**10a.** *[2 marks]*

Label region X and structure Y on the diagram of the kidney.




**10b.** *[2 marks]*

Distinguish between osmoregulators and osmoconformers.

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**11.** *[3 marks]*

Describe the role of ADH in human osmoregulation.

**12a.** *[2 marks]*

The Chinese soft-shelled turtle, *Pelodiscus sinensis*, lives in salt water marshes. The turtle can live under water and out of water.

These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

Initial experiments involved collecting nitrogen excretion data from *P. sinensis*. The turtle urinates both in water and out of water. When in water it allows waste products to be washed out of its mouth. When out of water it regularly dips its head into shallow water to wash its mouth. The table shows the mean rates of ammonia and urea excretion from the mouth and kidney over six days.

| | Excretion of nitrogen by the mouth / μmol $day^{-1}$ $g^{-1}$ turtle | | Excretion of nitrogen by the kidney / μmol $day^{-1}$ $g^{-1}$ turtle | |
|---|---|---|---|---|
| | Turtle submerged in water | Turtle out of water | Turtle submerged in water | Turtle out of water |
| **Ammonia** | 0.29 | 0.30 | 0.63 | 0.54 |
| **Urea** | 0.90 | 1.56 | 0.07 | 0.73 |

[Source: Reproduced with permission, Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

Deduce whether the excretion of ammonia or urea changes more when a turtle emerges from water.

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**12b.** *[3 marks]*

Compare and contrast the changes in urea excretion in the mouth with the changes in urea excretion in the kidney when a turtle emerges from the water.

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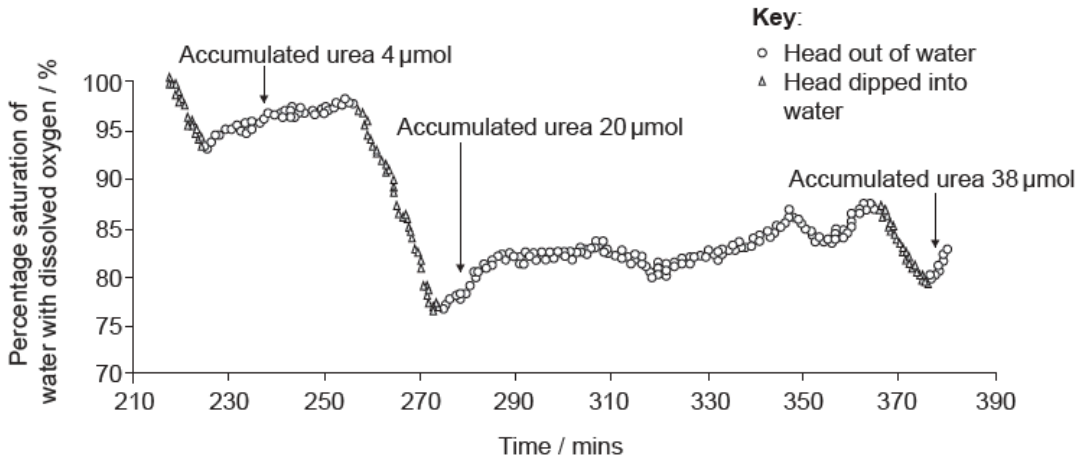
**12c.** *[1 mark]*

It was noted that during long periods out of water, turtles rhythmically moved their mouths to take in water from a shallow source and then discharge it. Changes in the dissolved oxygen and the quantity of accumulated urea in the rinse water discharged by the turtles were monitored over time as shown in this graph.




[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

Describe the trends shown by the graph for dissolved oxygen in water discharged from the mouth.

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**12d.** *[2 marks]*

Suggest reasons for these trends in dissolved oxygen.

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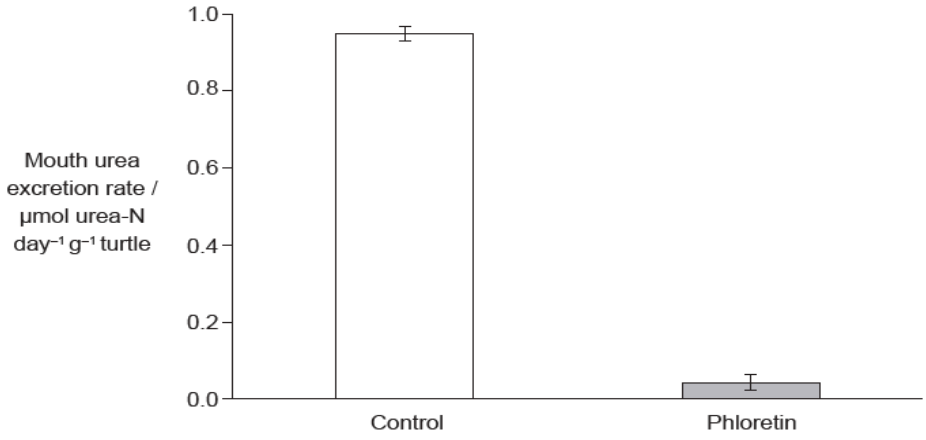
**12e.** *[2 marks]*

In order to test whether a urea transporter was present in the mouth tissues of the turtles, phloretin (a known inhibitor of membrane proteins that transport urea) was added to the water in which a further set of turtles submerged their heads. The results of that treatment are shown.




Deduce with a reason whether a urea transporter is present in the mouth of *P. sinensis*.

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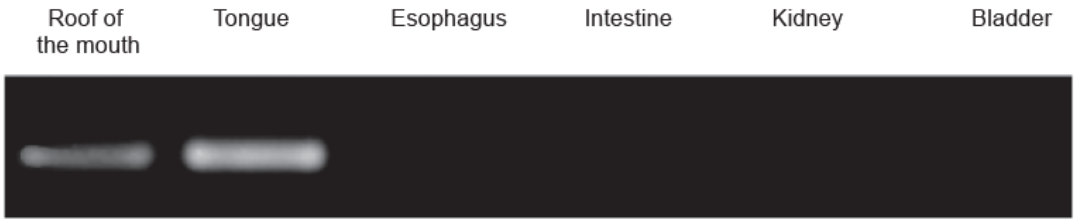
**12f.** *[2 marks]*

Further research was conducted to determine where mRNA expression of a urea transporter gene might be occurring in *P. sinensis*. Gel electrophoresis was used to analyse different tissue samples for mRNA activity.




Outline the additional evidence provided by the gel electrophoresis results shown above.

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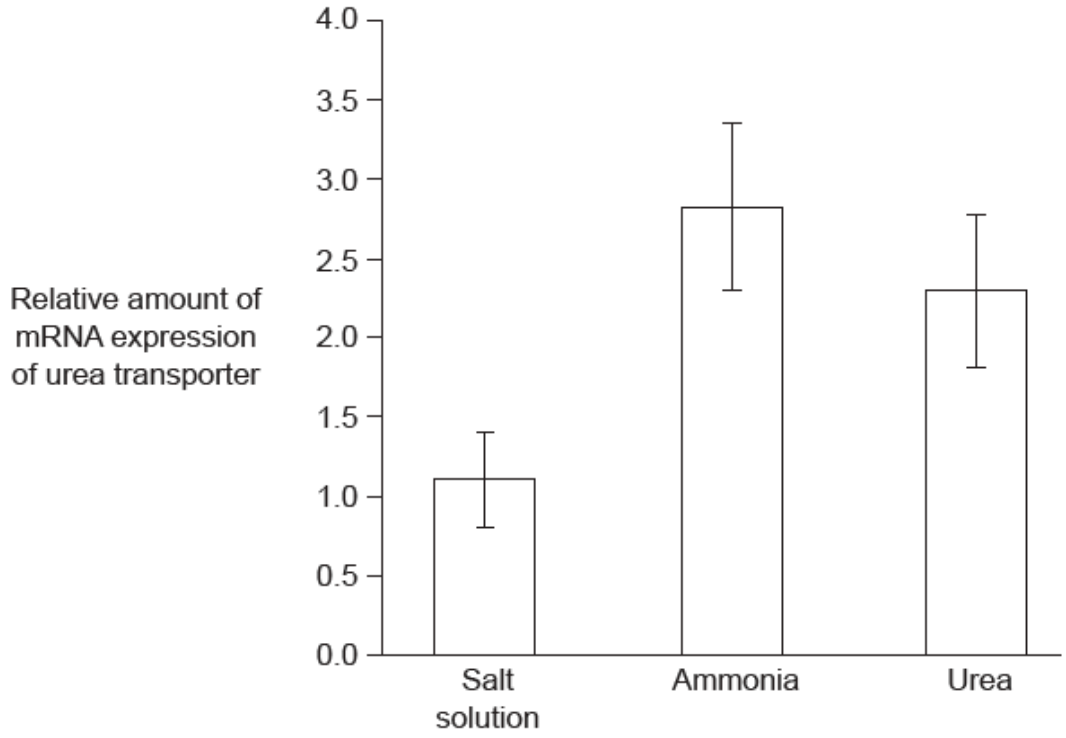
**12g.** *[1 mark]*

Expression of the urea transporter gene by cells in the turtle's mouth was assessed by measuring mRNA activity. Turtles were kept out of water for 24 hours and then injected with either a salt solution that matched the salt concentration of the turtle, dissolved ammonia or urea, followed by another 24 hours out of water.




Identify which of these turtle groups represent the control, giving a reason for your answer.

**12h.** *[2 marks]*

Suggest a reason for the greater expression of the gene for the urea transporter after an injection with dissolved ammonia than an injection of urea.

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**12i.** *[3 marks]*

The salt marshes where these turtles live periodically dry up to small pools. Discuss the problems that this will cause for nitrogen excretion in the turtles and how their behaviour might overcome the problems.

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**13.** *[7 marks]*

Explain how water balance is restored in mammals when they are dehydrated.

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**14.** *[8 marks]*

Water is the medium of life.

Explain the role of the kidney in osmoregulation.

**15.** *[4 marks]*

Outline the reasons for the differences in blood concentrations between the renal artery and the renal vein.

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**16.** *[7 marks]*

Explain how blood solute concentrations are kept within narrow limits in the human body.

**17.** *[8 marks]*

ADH (antidiuretic hormone) is a peptide hormone that is produced in the hypothalamus. Explain its action in the human body.

**18.** *[3 marks]*

The human circulatory system is structured to serve the organs and tissues of the body efficiently.

Distinguish between the composition of the blood of the renal artery and the blood of the renal vein.

**1.** *[1 mark]*

D

**2.** *[1 mark]*

A

**3.** *[1 mark]*

A

**4.** *[1 mark]*

A

**5.** *[1 mark]*

B

**6.** *[1 mark]*

B

**7.** *[1 mark]*

D

**8.** *[1 mark]*

B

**9.** *[1 mark]*

A

**10a.** *[2 marks]*

X: cortex ✔

Y: ureter ✔

**10b.** *[2 marks]*

## Markscheme

a. concentration constant inside osmoregulators versus variable inside osmoconformers ✔

b. internal solute concentration can differ from the external environment in osmoregulators versus same/equal in osmoconformers
***OR***
osmoregulators are independent of the external environment in solute concentration versus osmoconformers are tied to it ✔

c. birds/mammals/humans/freshwater fish are osmoregulators versus starfish/mussels/crabs/jellyfish/sea squirts/squid/sharks are osmoconformers ✔

**11.** *[3 marks]*

## Markscheme

a. secreted when blood/plasma is hypertonic/too concentrated/water content too low

b. makes walls of collecting duct/distal convoluted tubule «more» permeable to water

c. more aquaporins in membranes «of collecting duct cells»

d. more water reabsorbed from filtrate/from urine/more water returned to blood

e. small volume of concentrated urine excreted

***[Max 3 Marks]***

**12a.** *[2 marks]*

## Markscheme

a. urea

b. for both mouth and kidney

c. percentage change/change in µmol $day^{-1}$ $g^{-1}$ greater with urea/other acceptable numerical comparison

**12b.** *[3 marks]*

## Markscheme

a. both higher/increased on emergence from/with turtle out of water

b. both increased by 0.66 «$\mu mol^{-1}$ $g^{-1}$ when turtle emerges from water»

c. % increase is higher in kidney / kidney 940% versus mouth 73/75% / increase is higher proportionately higher in kidney / kidney x10 versus mouth nearly double/x1.73

d. urea excretion by mouth greater than kidney out of water «despite larger % increase in kidney excretion»

**12c.** *[1 mark]*

## Markscheme

decrease «when head is submerged» and increase when head is out of water

**12d.** *[2 marks]*

## Markscheme

a. oxygen absorbed from water/exchanged for urea when head dipped in water«so oxygen concentration decreases»

b. lungs cannot be used with head in water / can «only» be used with head out of water

c. oxygen from water «in mouth» used in «aerobic cell» respiration

d. oxygen from air dissolves in water when head out of water «so oxygen concentration increases»

**12e.** *[2 marks]*

## Markscheme

a. urea transporter is present

b. less urea «excreted»/ lower rate «of urea excretion» / excretion almost zero when phloretin/inhibitor was present

**12f.** *[2 marks]*

## Markscheme

a. mRNA only in mouth and tongue/in mouth and tongue but not esophagus intestine kidney or bladder

b. bands / lines indicate mRNA for/expression of urea transporter gene

c. urea transporter gene expressed / urea transporters in mouth/tongue / not expressed/made in esophagus/intestine/kidneys/bladder

d. mRNA/transcription/gene expression/urea transporters higher in tongue/more in tongue «than mouth»

**12g.** *[1 mark]*

## Markscheme

salt solution is control because it does not contain a nitrogenous/excretory waste product / it matches the salt concentration of the turtle / the turtle's body already contains salt / because the turtle lives in salt water/salt marshes / because nothing has been altered

**12h.** *[2 marks]*

## Markscheme

a. ammonia is «highly» toxic/harmful

b. ammonia is more toxic than urea/converse

c. ammonia converted to urea

d. urea concentration raised «by injecting ammonia»

e. difference between ammonia and urea «possibly» not «statistically» significant

**12i.** *[3 marks]*

## Markscheme

*Problems:*

a. urea becomes more concentrated «in small pools» / lower concentration gradient «between tongue/mouth and water»

b. less water available for urine production/excretion by kidney
***OR***
less water in ponds for mouth rinsing/more competition for pools (to use for mouth rinsing)

*Behaviour to overcome problems:*

c. «still able to» dip mouth into/mouth rinse in water/pools

d. «still able to» excrete urea «though the mouth» in the small pools

e. more conversion of ammonia to urea/urea excretion rather than ammonia

f. more urea transporters/expression of urea transporter gene

g. urea excreted «in mouth/via microvilli» by active transport/using ATP

h. excretion with little/no loss of water

**13.** *[7 marks]*

## Markscheme

a. thirst;
b. more water drunk / more water reabsorbed from feces (in the colon/large intestine);
c. osmoreceptors in the hypothalamus detect dehydration/high solute concentration in blood;
d. ADH secreted;
e. by the pituitary gland;
f. ADH signals to collecting duct/DCT (cells) to increase permeability to water;
g. more aquaporins (in plasma membranes of collecting duct/distal convoluted tubule cells);
h. more water reabsorbed from filtrate (in collecting ducts/distal convoluted tubules);
i. reabsorption by osmosis / reabsorption due to medulla being hypertonic;
j. reabsorbed water passes into the blood/reduces the solute concentration of blood;
k. smaller volume/more concentrated/hypertonic urine formed;
l. less sweating;

**14.** *[8 marks]*

## Markscheme

a. osmoregulation is regulation of water and solute/salt balance/solute concentrations;

b. nephron (is the functional unit of the kidney/osmoregulates);

c. ultrafiltration in glomerulus / glomerular filtrate collected by Bowman's capsule;

d. loop of Henle establishes/maintains hypertonic conditions in medulla;

e. osmosis/reabsorption of water (from filtrate) in the collecting duct;

f. brain/hypothalamus monitors blood solute concentration / pituitary secretes ADH;

g. ADH secreted when solute concentration of blood is too high/hypertonic/when dehydrated;

h. ADH increases permeability of collecting duct to water;

i. ADH causes more aquaporins (in membranes of collecting duct wall cells);

j. more water reabsorbed resulting in more concentrated/hypertonic urine/less volume of urine;

k. less/no ADH secreted when solute concentration (of blood) is too low/hypotonic;

l. less water reabsorbed resulting in dilute/hypotonic urine/large volume of urine;

*Reject 'water balance' and 'water concentration' for mpa*.

**15.** *[4 marks]*

## Markscheme

a. urea/waste products lower in vein due to excretion «in urine»/ultrafiltration but not reabsorption ✔

b. oxygen lower in vein due to use in cell respiration/in kidney tissue ✔

c. carbon dioxide higher in vein due to production by cell respiration/excretion by kidney cells ✔

d. glucose lower in vein due to use in cell respiration «by kidney tissue» ✔

e. sodium/chloride/ion concentrations changed due to production of hypertonic/hypotonic urine
***OR***
sodium/chloride/ion concentrations lower due to removal of excess ✔

f. ion/solute concentrations lower in vein than artery if ADH has been secreted
***OR***
ion/solute concentrations in vein vary depending on amount of water reabsorbed in the collecting duct ✔

g. drug/toxin concentrations lower in vein due to excretion in urine ✔

*Accept any point given as the converse.*

*Each mark point includes a difference and reason for it.*

**16.** *[7 marks]*

## Markscheme

a. solute concentration of blood monitored by the brain/hypothalamus ✔

b. pituitary gland secretes ADH ✔

c. ADH secreted when solute concentration/osmolarity is too high/a person is dehydrated/*OWTTE* ✔

d. collecting duct more permeable to water ✔

e. «more» aquaporins/opens aquaporins «in the plasma membrane of collecting duct cells» ✔

f. «more» water reabsorbed «into the medulla» ✔

g. medulla is hypertonic/hyperosmotic «so water can be reabsorbed from filtrate» ✔

h. small volume of urine/concentrated urine produced «with ADH» ✔

i. no/little/less ADH secreted if «blood» solute concentration is too low ✔

j. collecting duct less permeable to water/less water reabsorbed/large volume of urine produced/dilute urine produced «with low/no ADH» ✔

k. insulin causes blood glucose «concentration» to be reduced ✔

l. glucose stored as glycogen in the liver ✔

m. glucagon causes blood glucose «concentration» to be increased ✔

n. negative feedback ✔

*Accept hypertonic for solute concentration too high and hypotonic for too low.*

**17.** *[8 marks]*

## Markscheme

a. ADH plays a role in osmoregulation/regulating blood solute concentration ✔

b. acts on the collecting ducts of the kidney ✔

c. acts in «late» distal convoluted tubule ✔

d. hypothalamus detects plasma/blood osmolarity/solute concentration ✔

e. if plasma/blood is too concentrated/hypertonic, «posterior» pituitary releases ADH ✔

f. ADH stimulates insertion of aquaporins/water channels / increases permeability of collecting duct ✔

g. water moves «through aquaporins» by osmosis into the medulla/blood ✔

h. urine becomes more concentrated/smaller volume ✔

i. negative feedback occurs ✔ *OWTTE for negative feedback acceptable.*

j. if blood is hypotonic no ADH is released ✔

k. water is not reabsorbed from the collecting ducts/permeability of the collecting duct decreases ✔

l. urine becomes more dilute/less concentrated / higher volume ✔

*OWTTE for all mp.*

**18.** *[3 marks]*

## Markscheme

a. less urea/excretory waste products/creatinine in renal vein

b. less oxygen in the renal vein

c. more carbon dioxide in renal vein

d. less glucose in renal vein

e. concentration of sodium ions/chloride ions/pH at normal level in the renal vein whereas it is variable in renal artery

f. solute concentration/osmolarity/water balance at normal level in the renal vein whereas it is variable in renal artery

*Allow answers in a table format. For all these mark points accept the converse as long as it is clear whether the artery or vein has the higher amount.*

*Answers relating to volume and pressure are not relevant to the question.*