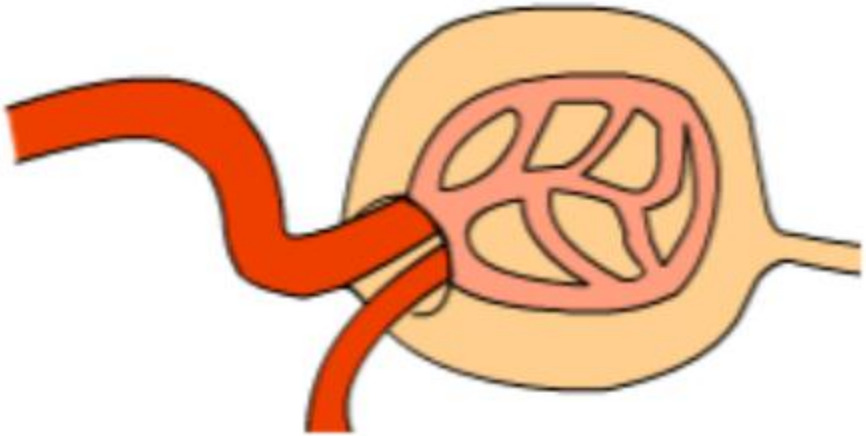
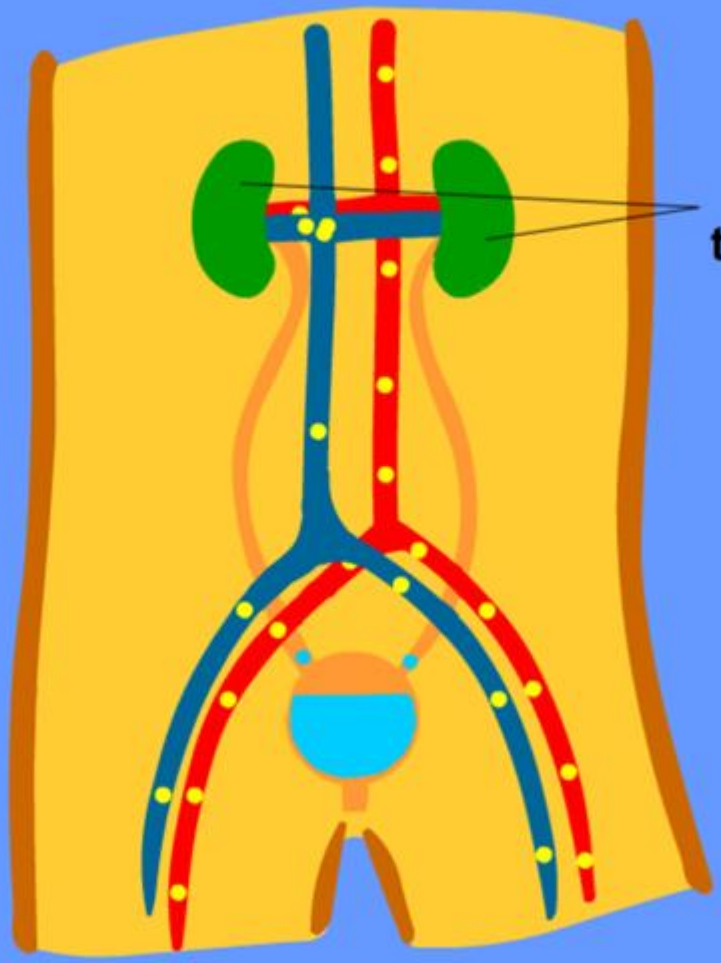


The Kidney

Stephen Taylor
Bandung International School

How Do Kidneys Work?



Here we see the kidneys purifying the blood of toxins and water

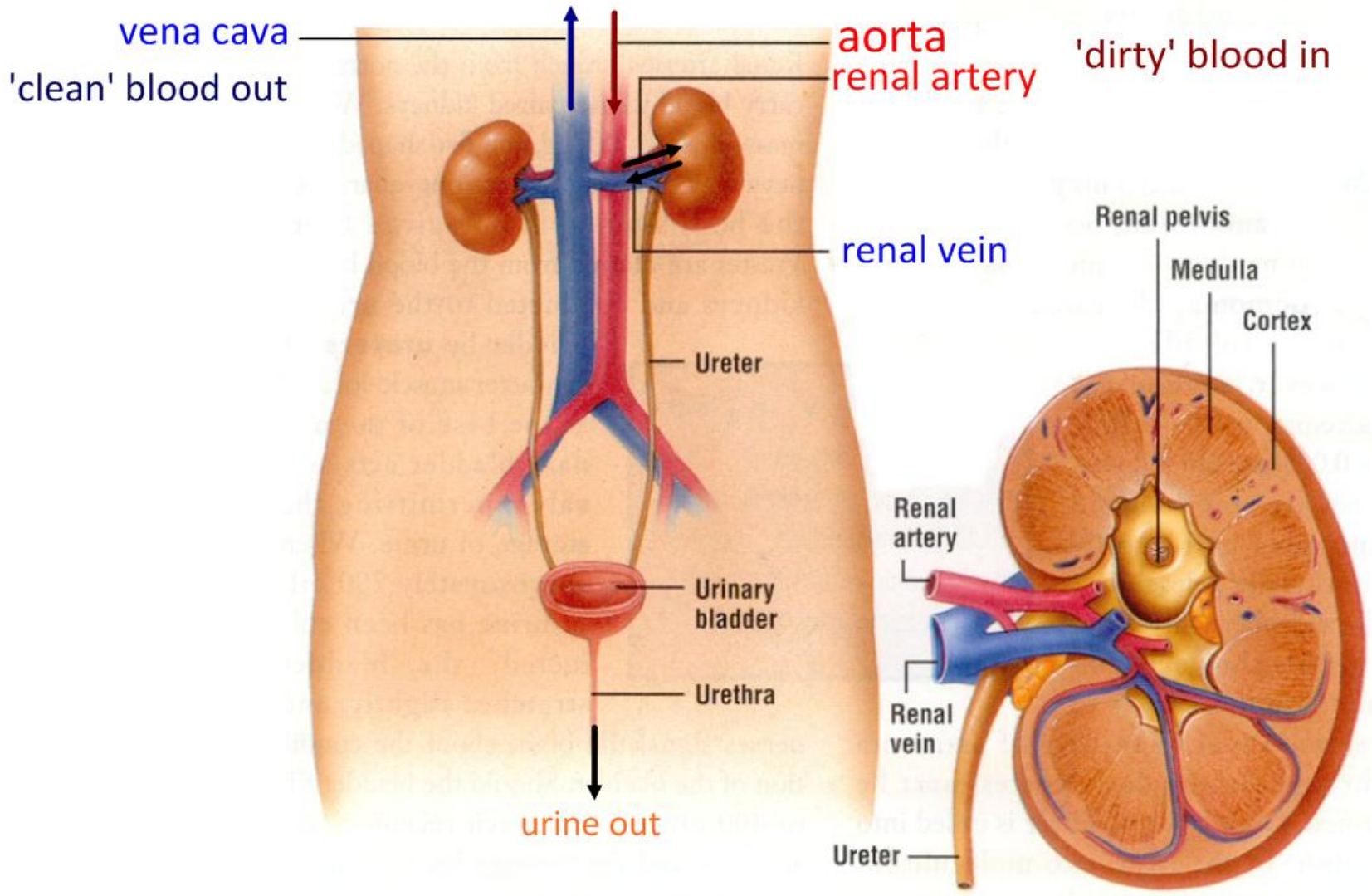
http://www.kidneypatientguide.org.uk/site/HKWanim.php

Excretion is the removal from the body of waste products of metabolism.

http://www.harvest-community.org/images/224.jpg

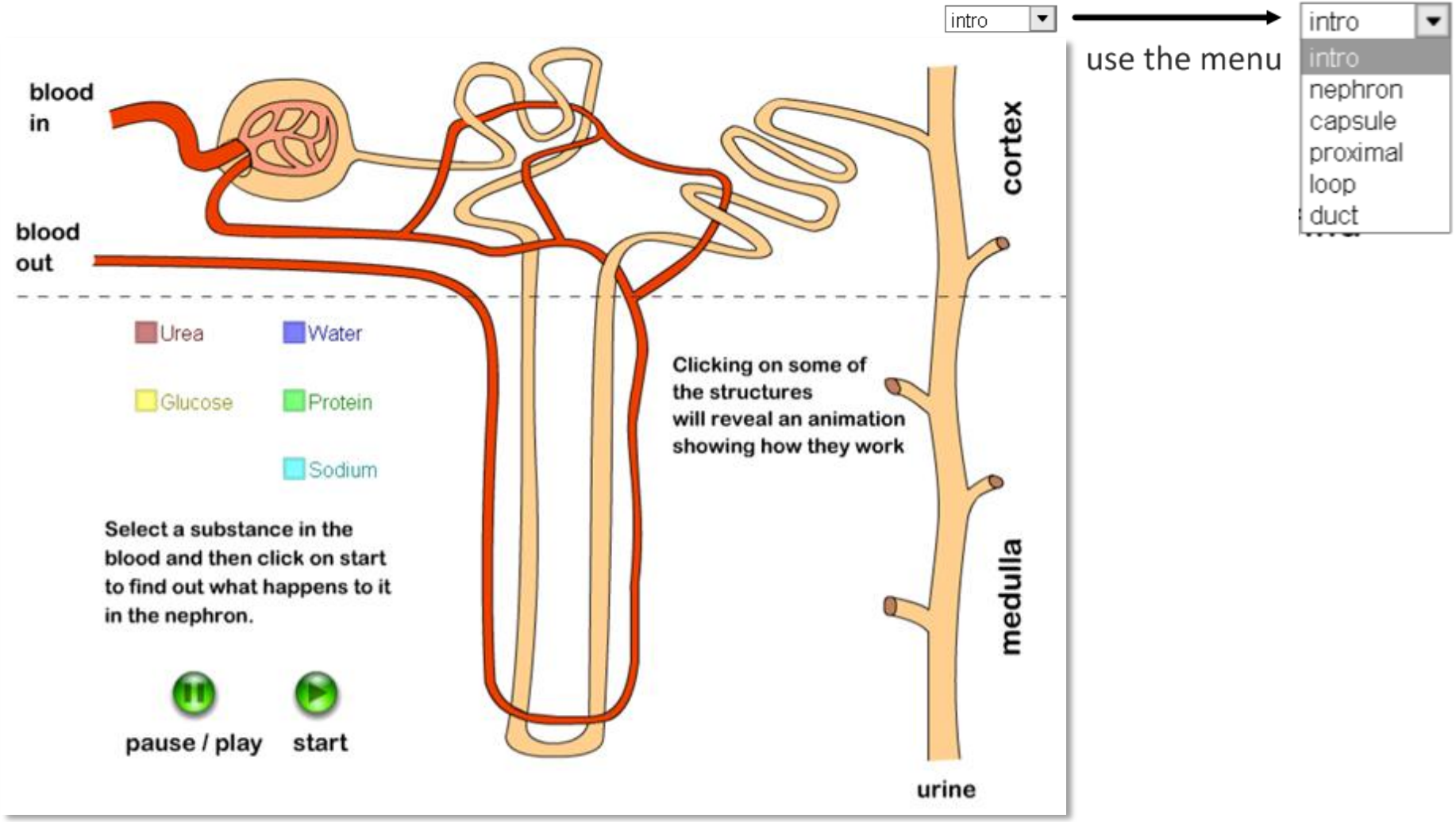
We don't consider defecation as excretion as faeces is not the waste product of metabolism - it is undigested food.

The Urinary (Excretory) System filters blood and produces urine



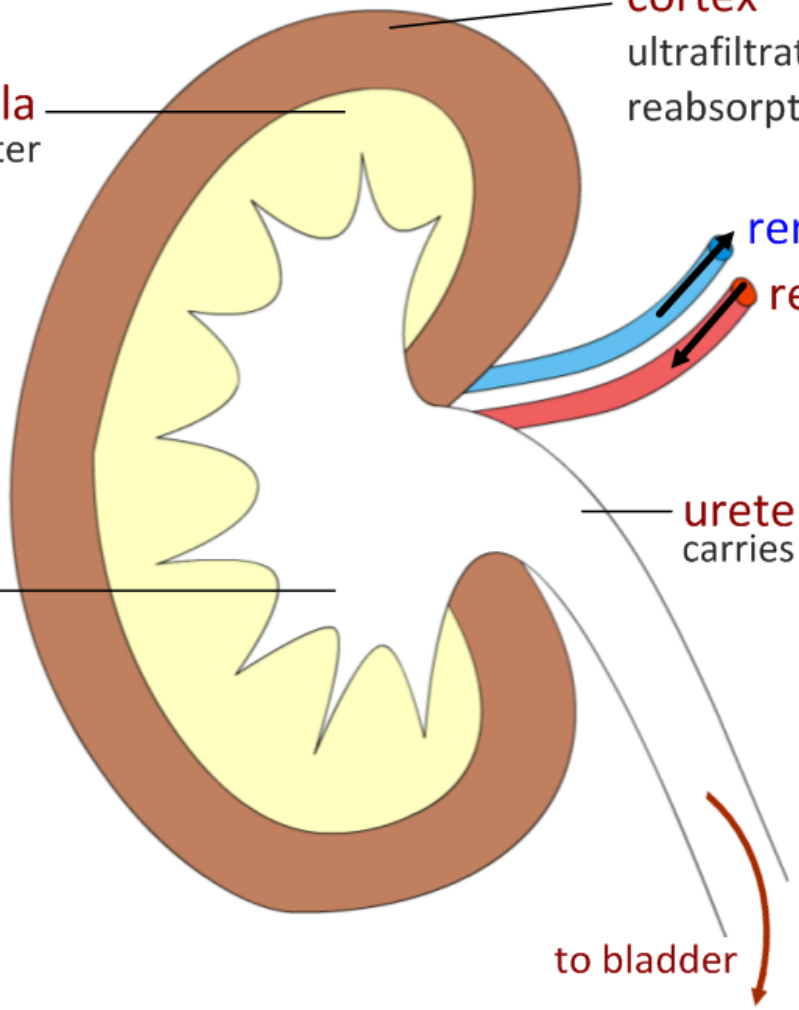
http://kvhs.nbed.nb.ca/gallant/biology/excretory_system_anatomy.html

This animation is clear and simple:



http://www.biologymad.com/resources/kidney.swf

The Kidney is the blood's filtration and balancing system



cortex
ultrafiltration and selective reabsorption of blood contents

medulla
reabsorption of water

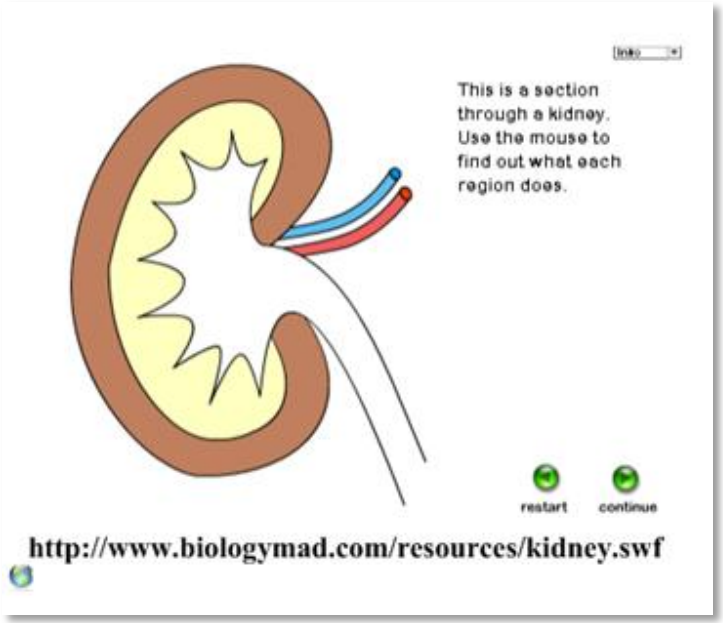
renal vein (balanced blood)

renal artery (unbalanced blood)

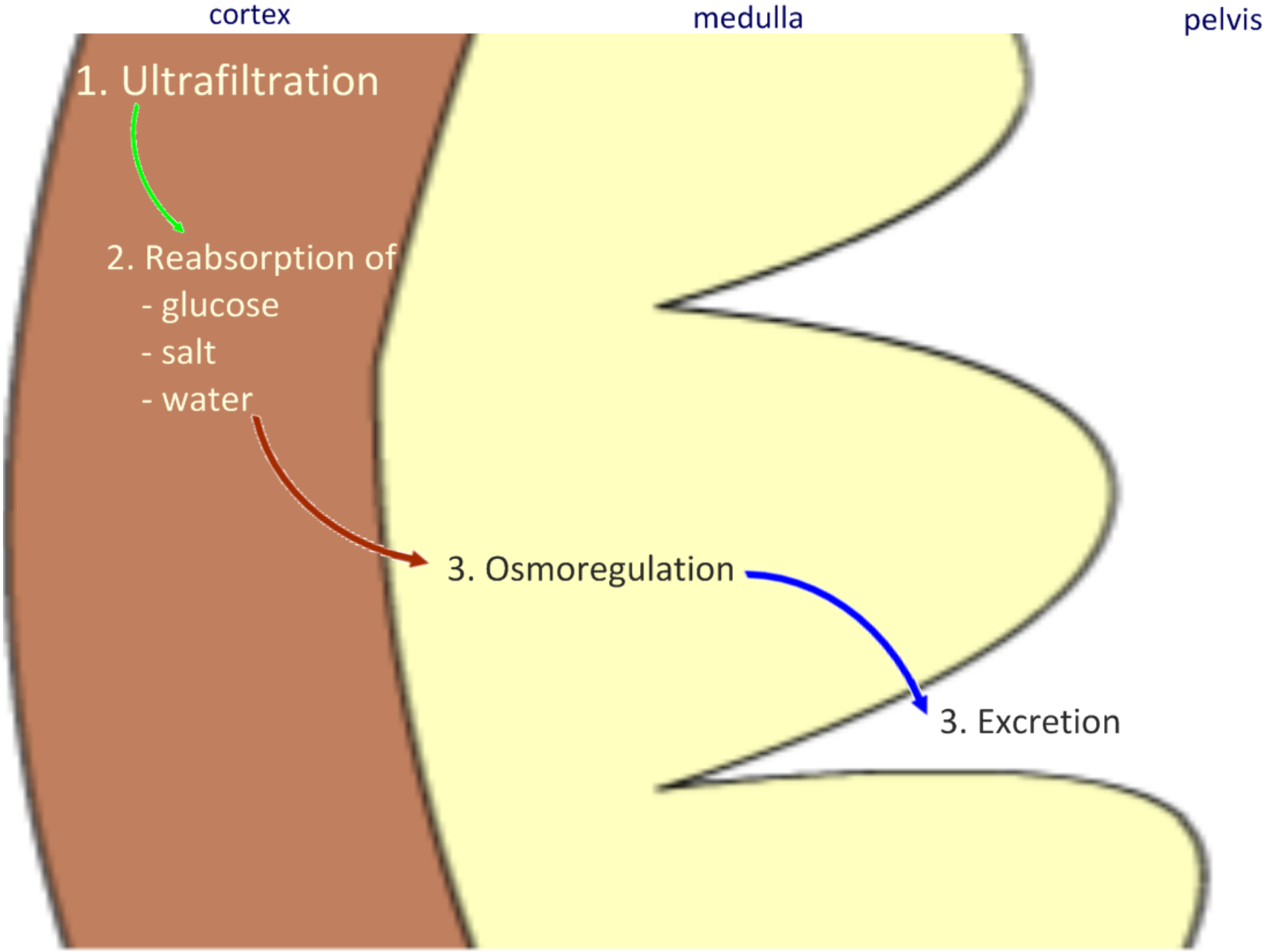
ureter
carries urine to the bladder

pelvis
collecting ducts deliver urine to the pelvis to be passed on to the ureter

to bladder

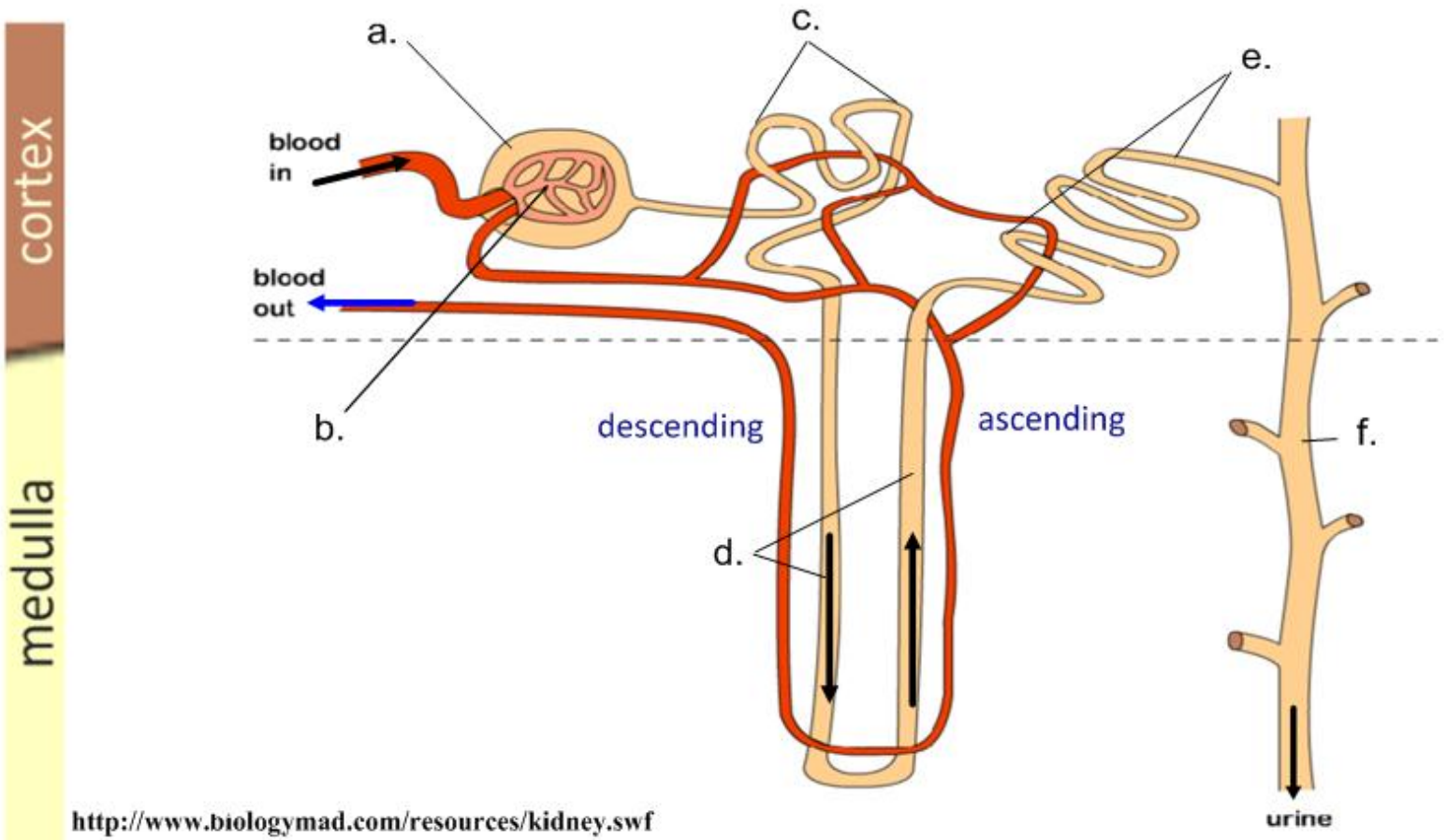


Balancing the blood



The Nephron is the functional unit of the kidney

There are around one million in each kidney



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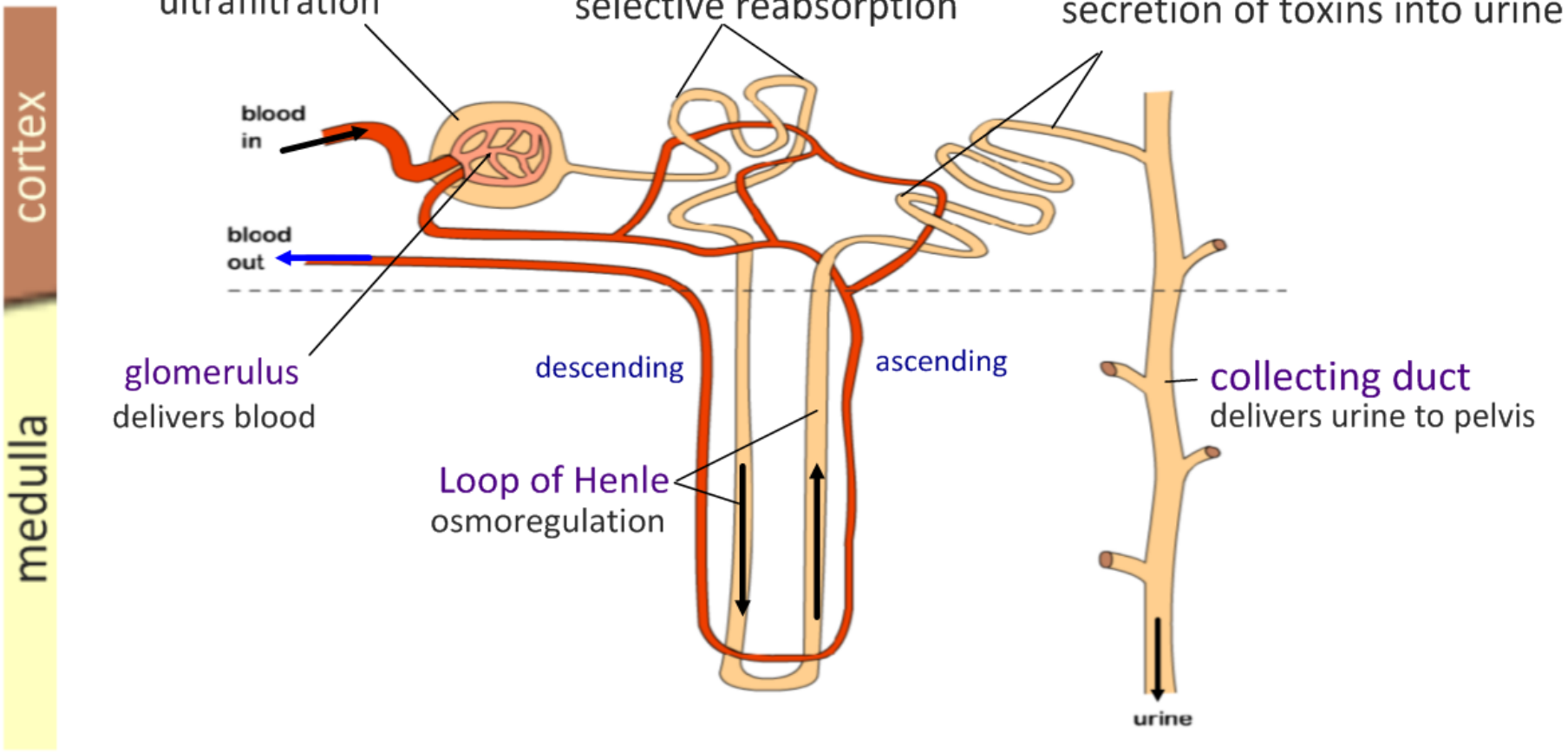

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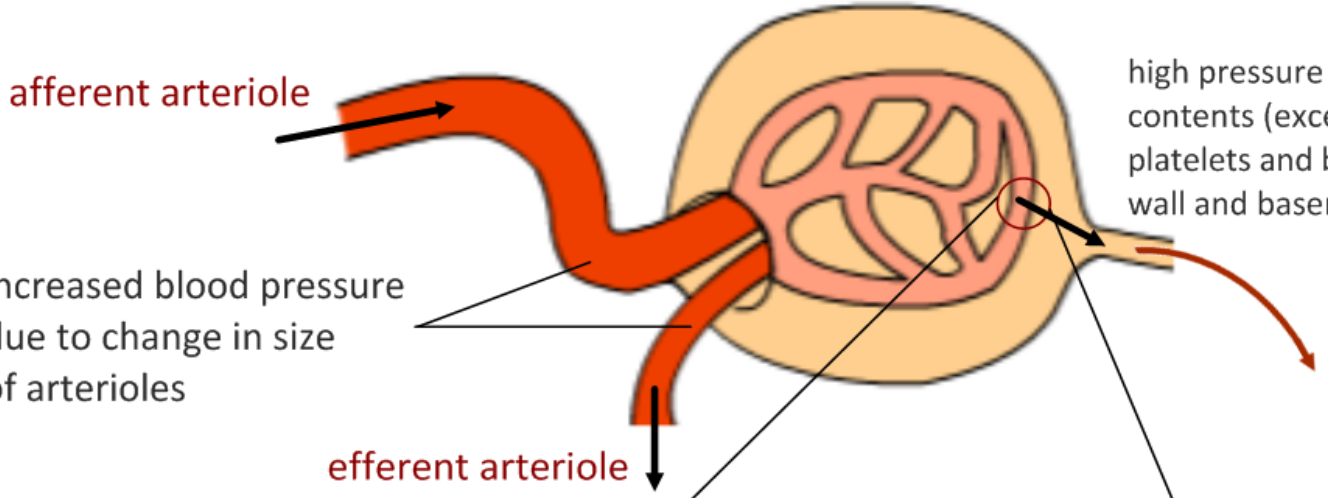
Ultrafiltration occurs in the renal capsule

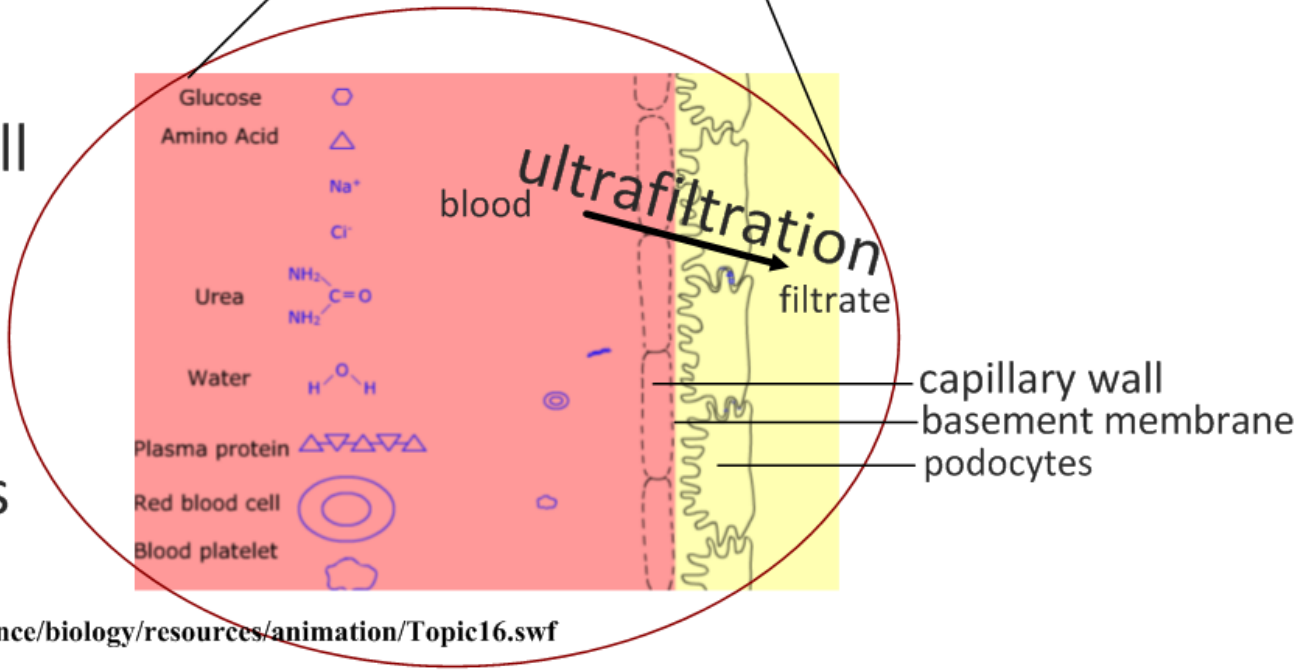


high pressure forces water and blood contents (except large plasma proteins, platelets and blood cells) across the capillary wall and basement membrane.

increased blood pressure due to change in size of arterioles

glomerular filtrate continues through the nephron

The capillary wall and basement membrane are **fenestrated:** they have pores



http://cd1.edb.hkedcity.net/cd/science/biology/resources/animation/Topic16.swf

Explain the process of ultrafiltration.

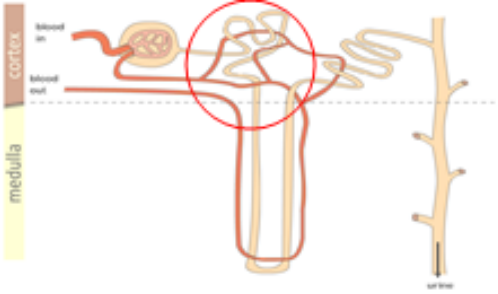
(8 marks)

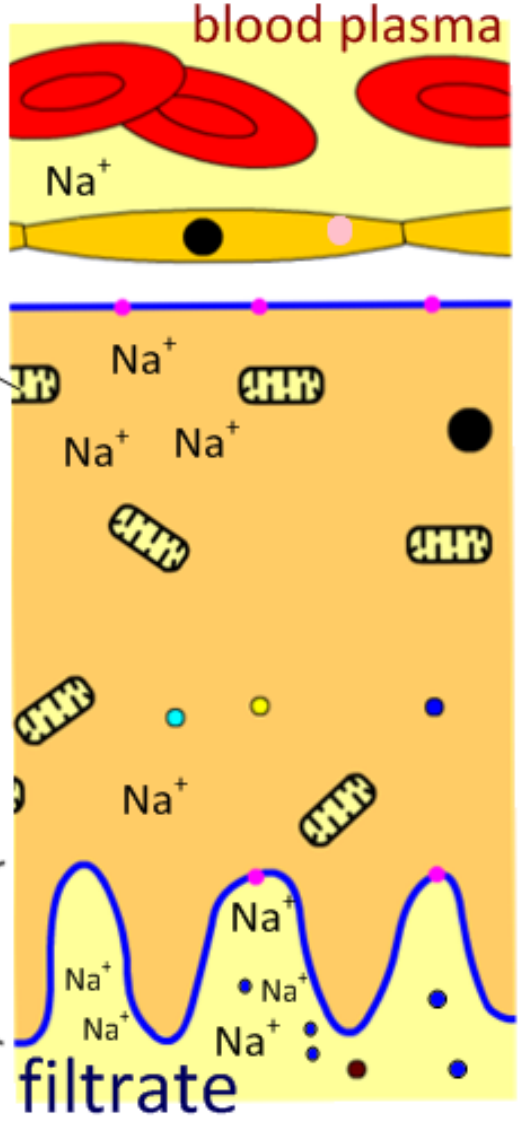
Explain the process of ultrafiltration.

(8 marks)

Ultrafiltration occurs in the renal capsule;
In the cortex of the kidney;
Blood enters the afferent arteriole and leaves the efferent arteriole;
The afferent arteriole is larger than the efferent arteriole,
causing high pressure in the renal capsule;
Water, glucose, amino acids and solutes are forced out of blood
(including metabolic wastes);
Through fenestrated capillaries and basement membrane;
Podocyte cells act as a filter;
Plasma proteins, platelets and cells are large, so remain in blood;
Glomerular filtrate is carried through the nephron;
Where selective reabsorption takes place in the proximal convoluted tubule.

Selective reabsorption of glucose, water and salts occurs in the proximal convoluted tubule (PTC)





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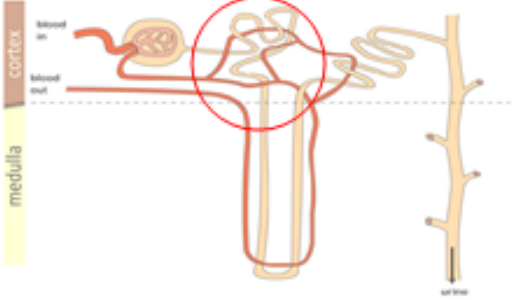

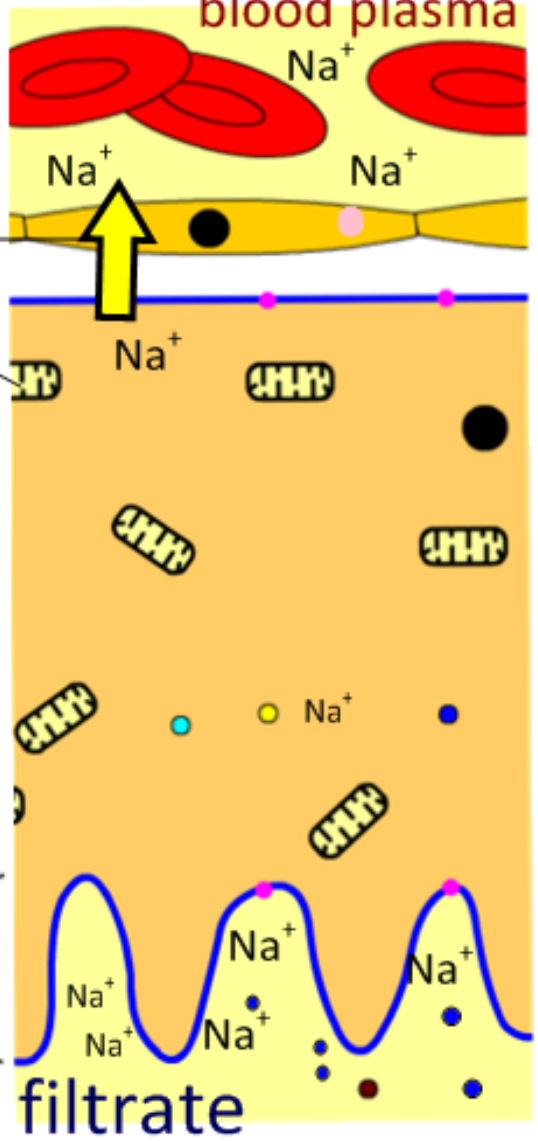

Active transport of sodium ions (Na^+) from PTC cells into blood plasma...

mitochondria produce ATP for active transport

microvilli increase surface area for reabsorption

channel proteins are also present

http://www.biologymad.com/resources/kidney.swf

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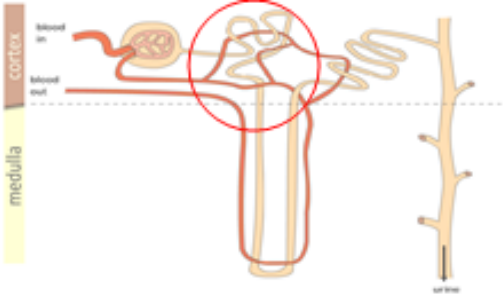


Active transport of sodium ions (Na^+) from PTC cells into blood plasma...

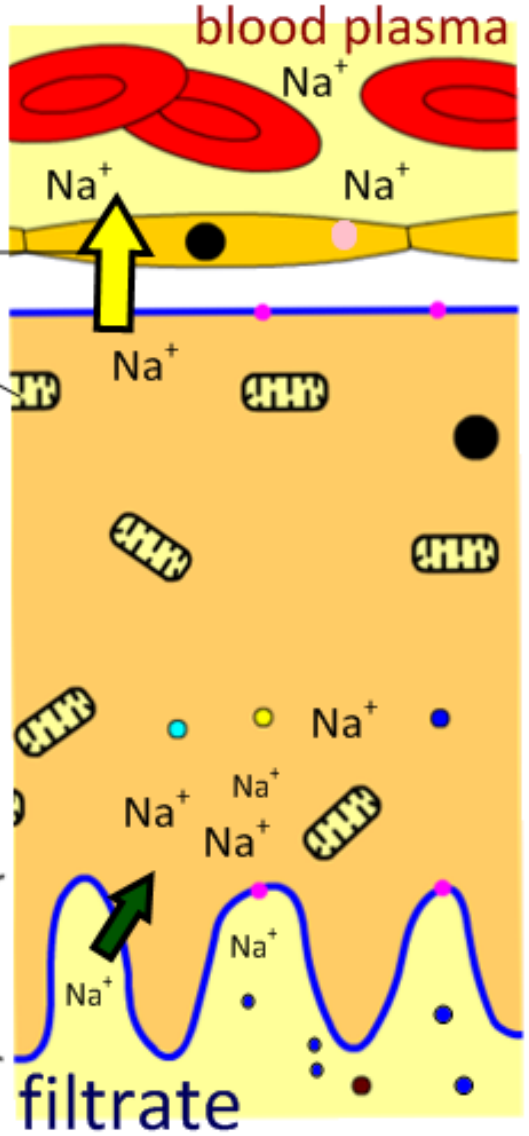
mitochondria produce ATP for active transport

...generates a concentration gradient between the filtrate and the PTC cells...

...so Na^+ enters cells from lumen by facilitated diffusion, down the concentration gradient.

microvilli increase surface area for reabsorption

channel proteins are also present



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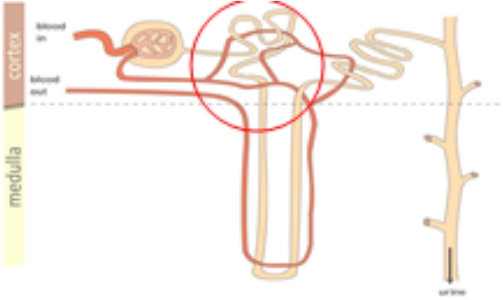

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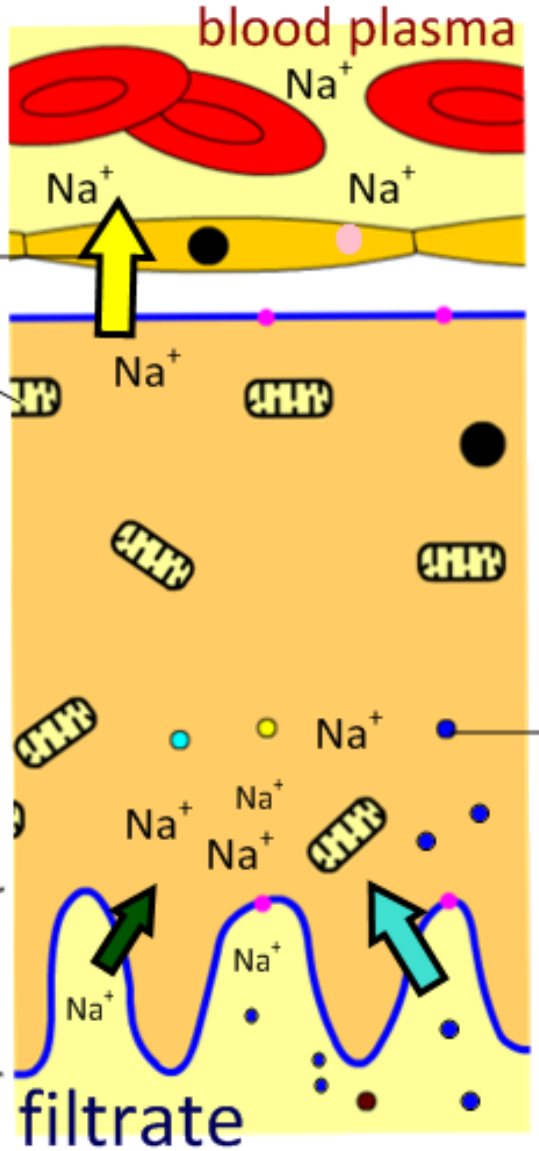


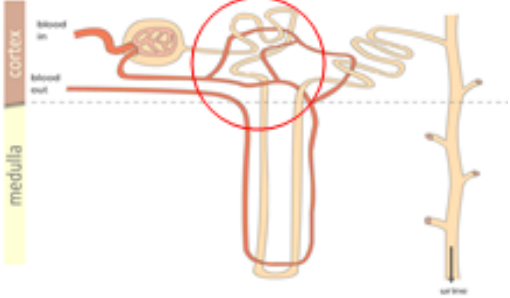
The flow of Na^+ ions into the PTC cells leads to cotransport of amino acids and glucose from filtrate in lumen into the cells.

Increase in solute concentration due to inflow of Na^+ leads to osmosis of water into the cells of the proximal convoluted tubule.

some urea also diffuses back in

http://www.biologymad.com/resources/kidney.swf

Selective reabsorption of glucose, water and salts occurs in the proximal convoluted tubule (PTC)



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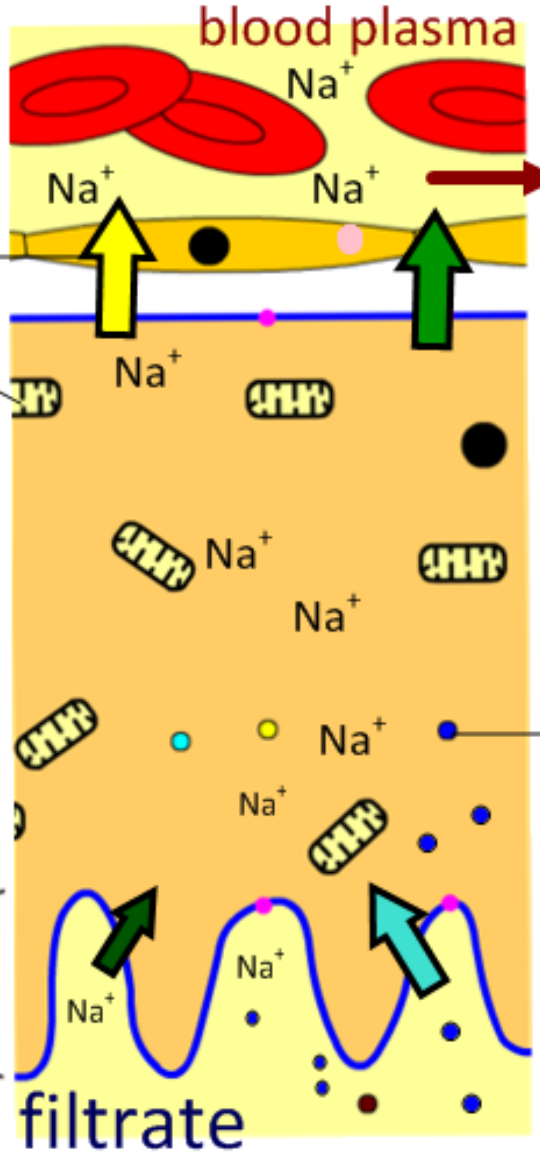

Glucose and amino acids enter capillaries through facilitated diffusion. Blood flow maintains concentration gradient.

The flow of Na^+ ions into the PTC cells leads to cotransport of amino acids and glucose from filtrate in lumen into the cells.

Increase in solute concentration due to inflow of Na^+ leads to osmosis of water into the cells of the proximal convoluted tubule.

some urea also diffuses back in

http://www.biologymad.com/resources/kidney.swf

Explain selective reabsorption in the kidney.

(8 marks)

Explain selective reabsorption in the kidney.

(8 marks)

Water, salts, amino acids and glucose in glomerular filtrate need to be reabsorbed;
Selective reabsorption occurs in proximal convoluted tubule of nephron;
Convolutions and microvilli increase surface area for reabsorption;
Large numbers of mitochondria present in PTC cells, generate ATP;
Active transport pumps Na^+ ions from PTC cells into capillaries;
Generating concentration gradient between PTC cells and filtrate in lumen;
Na^+ ions move from lumen to PTC cells by facilitated diffusion;
Glucose and amino acids follow by cotransport;
Solute concentration increases in PTC cells;
Leading to osmosis of water from lumen into PTC cells;
Facilitated diffusion carries glucose and amino acids into blood;
Flow of blood maintains concentration gradient.
65-80% of water is recovered;
100% glucose and amino acids recovered;
Some urea also diffuses back into the blood.

Osmoregulation is the control of the water balance of the blood, tissue or cytoplasm of a living organism.

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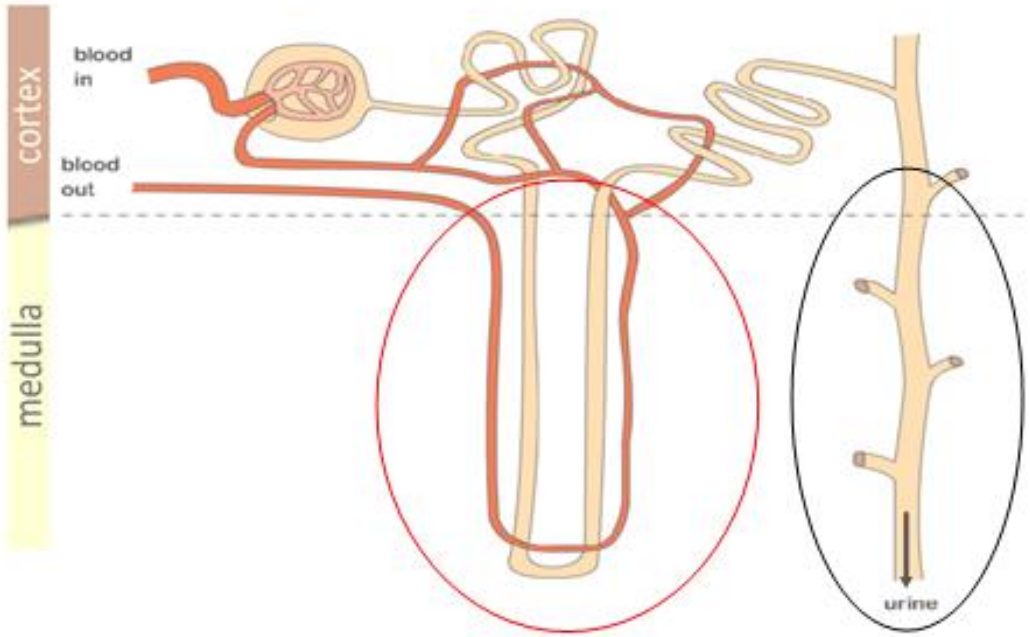
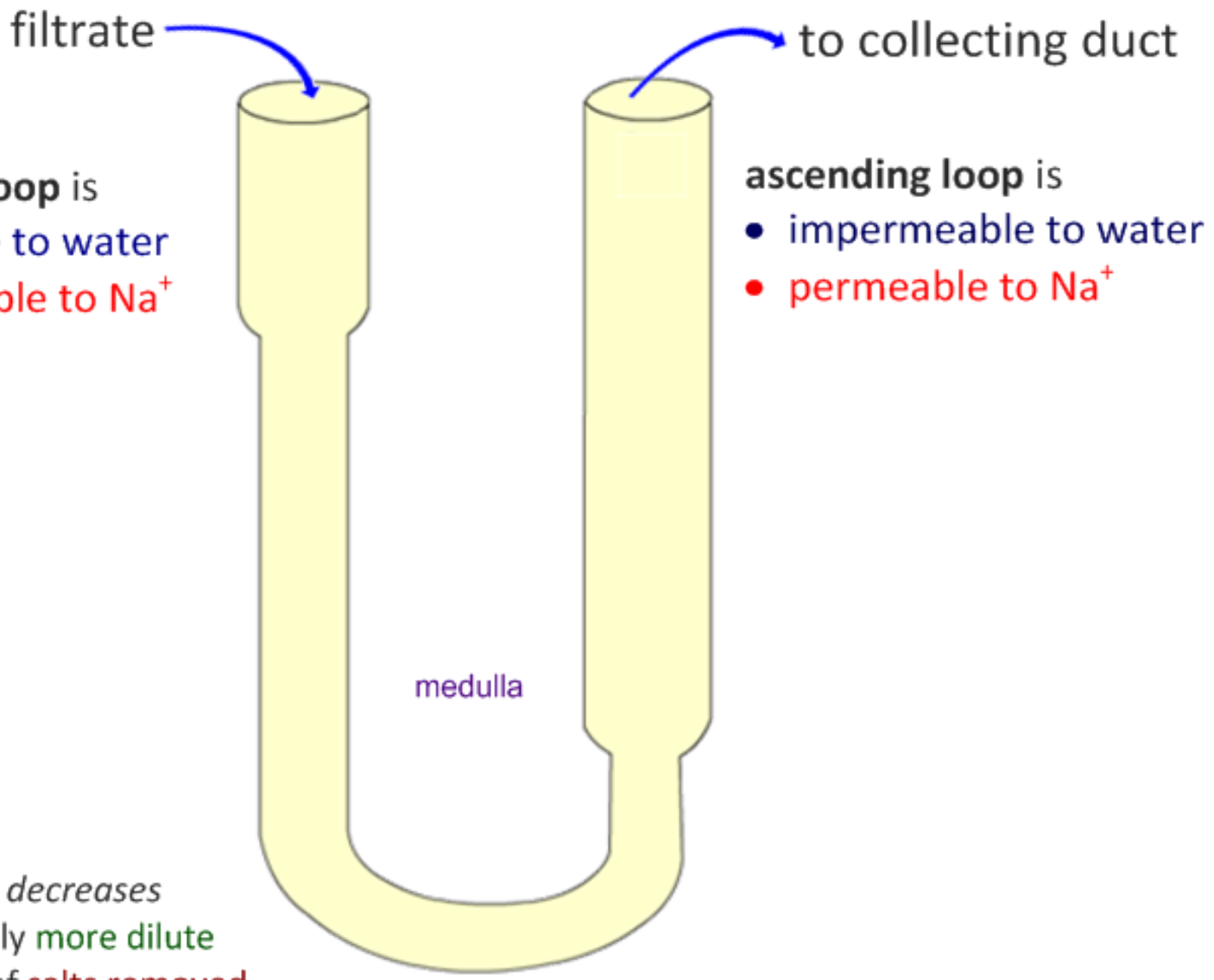


The *Loop of Henle* generates a high concentration of solutes in the cells and fluid of the medulla.

The *collecting duct* balances the water concentration of the blood, through hormonal control.

http://www.biologymad.com/resources/kidney.swf

The *Loop of Henle* generates a high concentration of solutes in the cells and fluid of the medulla. Output of urine is more dilute than input.



descending loop is
- permeable to water
- impermeable to Na^+

ascending loop is
- impermeable to water
- permeable to Na^+

Overall effects:
- filtrate volume *decreases*
- ouptut is slightly more dilute
- large amount of salts removed

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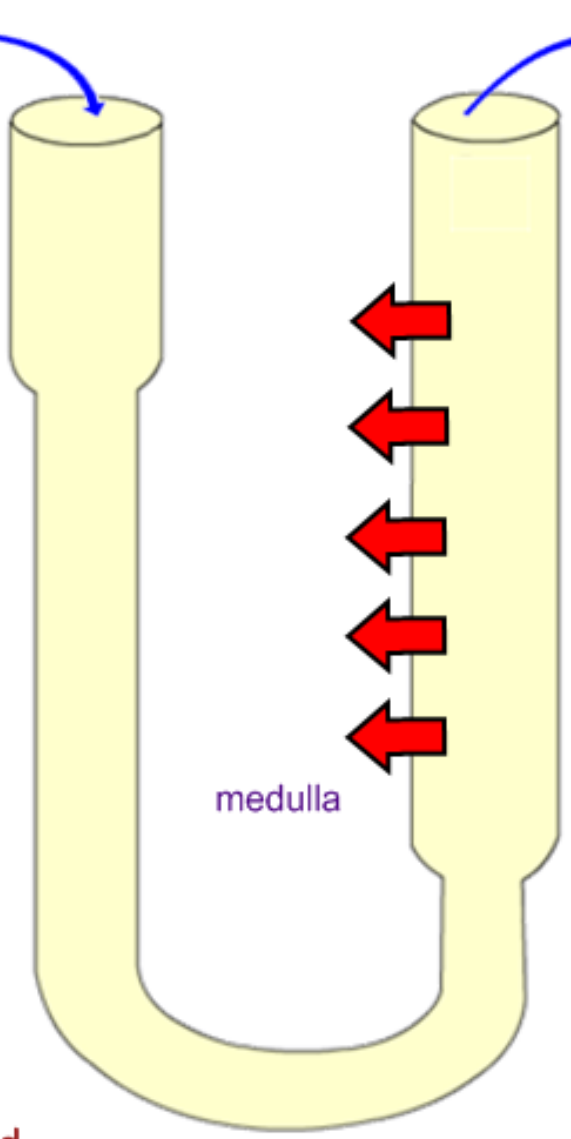

descending loop is
- permeable to water
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ascending loop is
- impermeable to water
- permeable to Na^+

Na^+ is pumped into the medulla by active transport.

Cl^- ions follow.

Solute concentration in filtrate decreases as loop ascends.

Countercurrent effect facilitates changes in the Loop of Henle.

Overall effects:
- filtrate volume *decreases*
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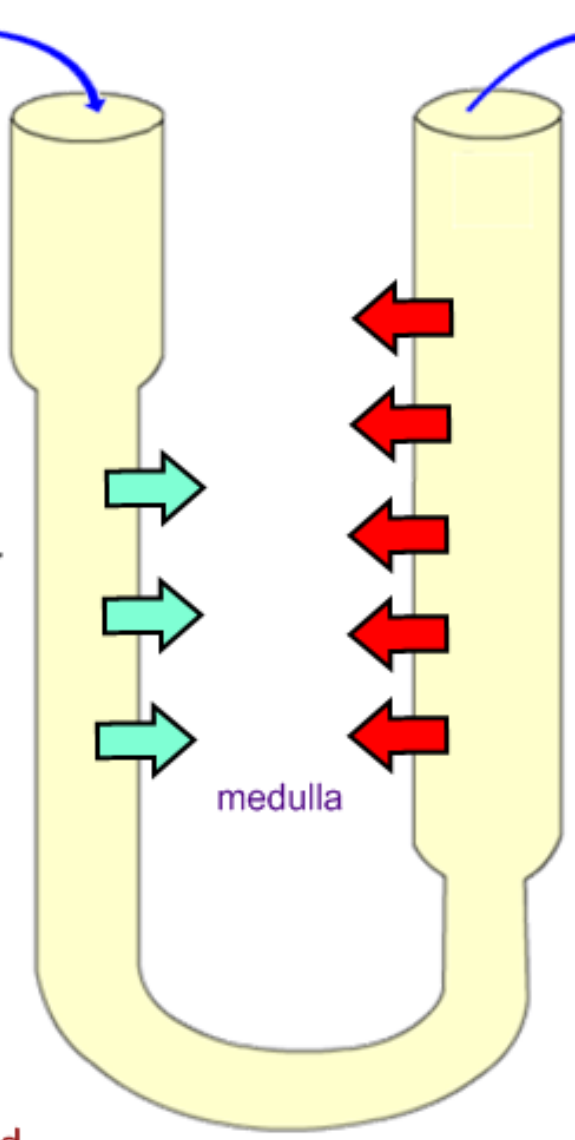


descending loop is
- permeable to water
- impermeable to Na^+

As solute concentration increases in medulla, an osmotic gradient is established. Some water leaves filtrate by osmosis.

Solute concentration in filtrate increases as loop descends.

Overall effects:
- filtrate volume *decreases*
- output is slightly more dilute
- large amount of salts removed

ascending loop is
- impermeable to water
- permeable to Na^+

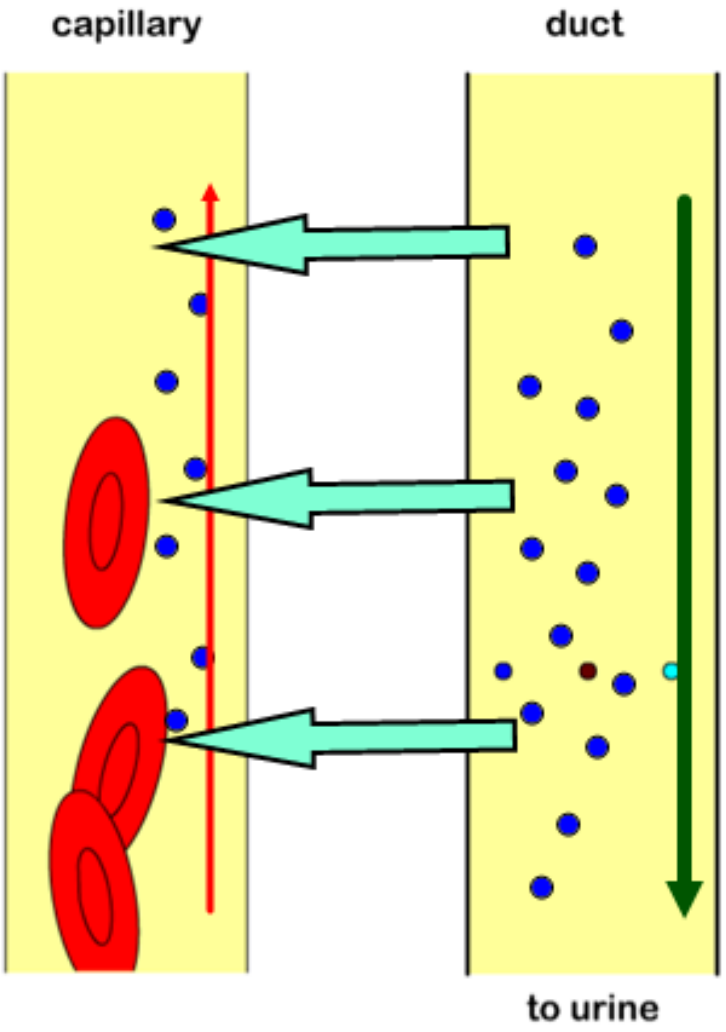
Na^+ is pumped into the medulla by active transport.

Cl^- ions follow.

Solute concentration in filtrate decreases as loop ascends.

Countercurrent effect facilitates changes in the Loop of Henle.

The *collecting duct* balances the water concentration of the blood, through hormonal control.

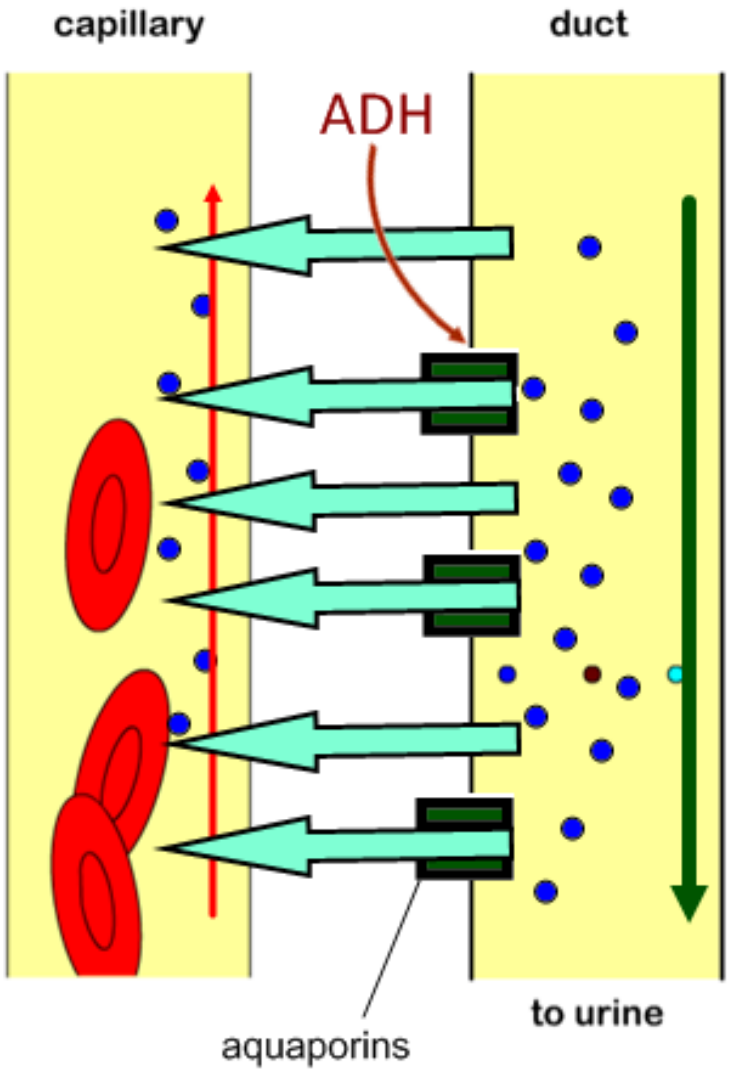


Filtrate enters the collecting duct from the distal convoluted tubule.

Water moves from the collecting duct to the capillaries by osmosis.

They flow in opposite directions, maintaining a concentration gradient - a *counter-current system*.

The *collecting duct* balances the water concentration of the blood, through hormonal control.



Filtrate enters the collecting duct from the distal convoluted tubule.

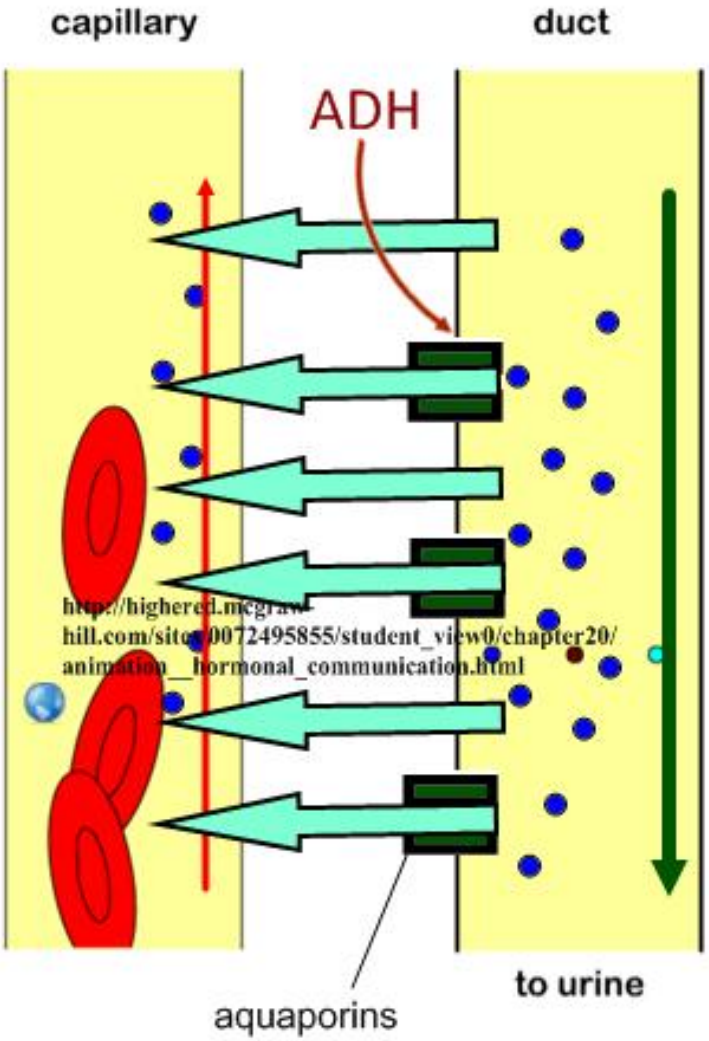
Water moves from the collecting duct to the capillaries by osmosis.

They flow in opposite directions, maintaining a concentration gradient - a *counter-current system*.

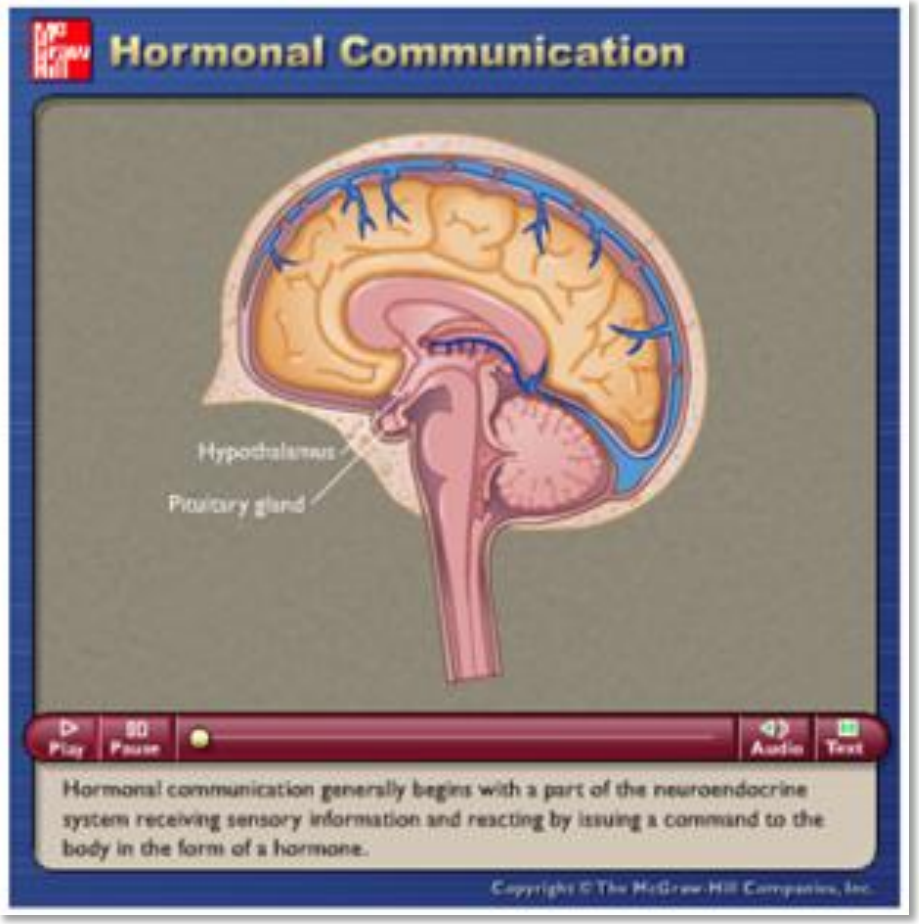
If a person is dehydrated, ADH (a hormone) acts on the walls of the collecting duct, producing aquaporins (channels) making it more permeable to water.

More water is transferred into the blood.
Urine output is hypertonic (high solute concentration).

The *collecting duct* balances the water concentration of the blood, through hormonal control.



Osmoregulation is an example of negative feedback control using hormones. Water content of blood is monitored by the hypothalamus and regulated by the pituitary gland.



http://tinyurl.com/4wjwwej

Explain osmoregulation in the kidney.

(8 marks)

Explain osmoregulation in the kidney.

(8 marks)

Osmoregulation takes place in the Loop of Henle and collecting duct;
In the medulla;

Loop of Henle
Descending limb is permeable to water but not to Na^+;
Descending limb is permeable to Na^+ but not to water;
Na^+ is pumped out of the ascending limb into the medulla;
Generating osmotic potential between nephron and medulla;
Some water leaves descending loop by osmosis;
Output is reduced volume, reduced salt concentration;

Collecting duct
Filtrate enters collecting duct from distal convoluted tubule;
Countercurrent flow of blood in capillaries and filtrate in duct
maintains concentration gradient- osmosis of water into blood;
Dehydration (detected by hypothalamus) leads to release of ADH (by pituitary);
ADH opens aquaporins (water channels) in walls of duct;
Increased transfer of water into blood, therefore hypertonic urine;
Excess water in blood leads to break down of aquaporins and hypotonic urine.

Explain the differences in concentrations of glucose, proteins and urea between the blood, glomerular filtrate and urine.

(8 marks)

What is filtered, reclaimed and excreted by the kidney?

This figure shows the amount of various substances filtered, reabsorbed and excreted by the kidney.

Substance	Filtered	Reabsorbed	Excreted
Sodium ions	26000	25850	150
Chloride ions	19000	18800	200
Urea	870	460	410
Glucose	800	800	nil
Amino Acids	400	400	nil
Water	180000	179000	1000

http://library.thinkquest.org/22016/excretion/index.html

1. Which nutrients are 100% reabsorbed?

Where does this happen?

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1. Which nutrients are 100% reabsorbed?

   Glucose and Amino Acids

   Where does this happen?

   Selective reabsorption in the proximal convoluted tubule

What is filtered, reclaimed and excreted by the kidney?

Composition of plasma, nephric filtrate, and urine (each in **g/100 ml** of fluid). These are representative values. The values for salts are especially variable, depending on salt and water intake.

Component	Plasma	Nephric Filtrate	Urine	Concentration	% Reclaimed
Urea	0.03	0.03	1.8		50%
Uric acid	0.004	0.004	0.05	12.5x	91%
Glucose	0.10	0.10	None	-	100%
Amino acids	0.05	0.05	None	-	100%
Total inorganic salts	0.9	0.9	<0.9–3.6	<1–4X	99.5%
Proteins and other macromolecules	8.0	None	None	-	-

http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/K/Kidney.html

2. The concentration of uric acid is 12.5x greater in the urine than in the filtrate or the blood.
   How much more concentrated is urea in the urine than in the blood?

Why is such a large proportion of urea and uric acid excreted?

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   How much more concentrated is urea in the urine than in the blood?

   60X (1.8 g/100ml ÷ 0.03 g/100ml)

   Why is such a large proportion of urea and uric acid excreted?

   They are very toxic

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http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/K/Kidney.html

3. What percentage of the following are forced into the nephron by ultrafiltration?

urea

glucose

inorganic salts

proteins and macromolecules

→ Can you explain this result?

What is filtered, reclaimed and excreted by the kidney?

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urea 100%
glucose 100%
inorganic salts 100%
proteins and macromolecules 0%

Can you explain this result?

They are too large for ultrafiltration

What other components of blood are not processed by ultrafiltration?

What is filtered, reclaimed and excreted by the kidney?

Composition of plasma, nephric filtrate, and urine (each in **g/100 ml** of fluid). These are representative values. The values for salts are especially variable, depending on salt and water intake.

Component	Plasma	Nephric Filtrate	Urine	Concentration	% Reclaimed
Urea	0.03	0.03	1.8		50%
Uric acid	0.004	0.004	0.05	12.5x	91%
Glucose	0.10	0.10	None	-	100%
Amino acids	0.05	0.05	None	-	100%
Total inorganic salts	0.9	0.9	<0.9–3.6	<1–4X	99.5%
Proteins and other macromolecules	8.0	None	None	-	-

http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/K/Kidney.html

3. What percentage of the following are forced into the nephron by ultrafiltration?

urea 100%
glucose 100%
inorganic salts 100%
proteins and macromolecules 0%

→ Can you explain this result?

They are too large for ultrafiltration

What other components of blood are not processed by ultrafiltration?

Erythrocytes, lymphocytes, platelets

What is wrong with this patient?

Composition of plasma, nephric filtrate, and urine (each in **g/100 ml** of fluid). These are representative values. The values for salts are especially variable, depending on salt and water intake.

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http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/K/Kidney.html

3. What is wrong with these data?

What is wrong with this patient?

Composition of plasma, nephric filtrate, and urine (each in **g/100 ml** of fluid). These are representative values. The values for salts are especially variable, depending on salt and water intake.

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http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/K/Kidney.html

3. What is wrong with these data?

Glucose found in the urine

What does this indicate?

What is wrong with this patient?

Composition of plasma, nephric filtrate, and urine (each in **g/100 ml** of fluid). These are representative values. The values for salts are especially variable, depending on salt and water intake.

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http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/K/Kidney.html

3. What is wrong with these data?

Glucose found in the urine

What does this indicate?

The patient may have diabetes

Explain the presence of glucose in the urine of a diabetic patient.

(8 marks)

How does diabetes lead to glucose in the urine?

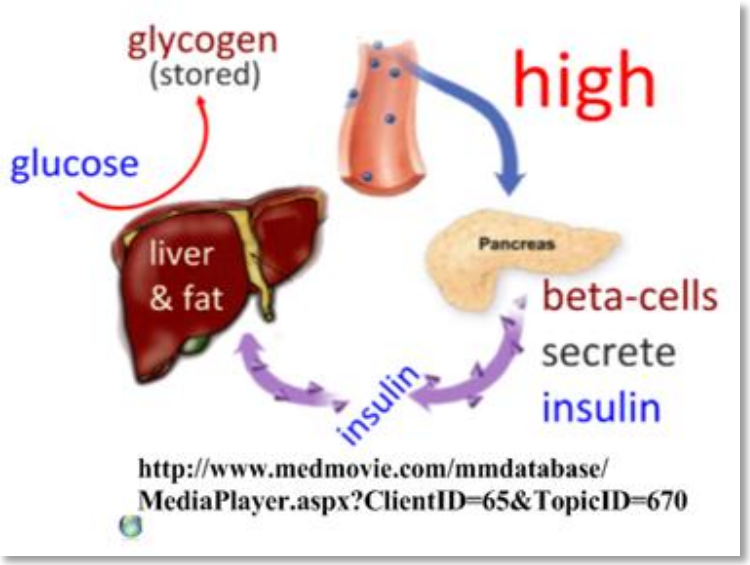
Type I: insulin not produced

liver does not take up glucose from blood

Type II: insulin receptors inactive

liver does not take up glucose from blood

End result: Blood sugar concentration remains high.



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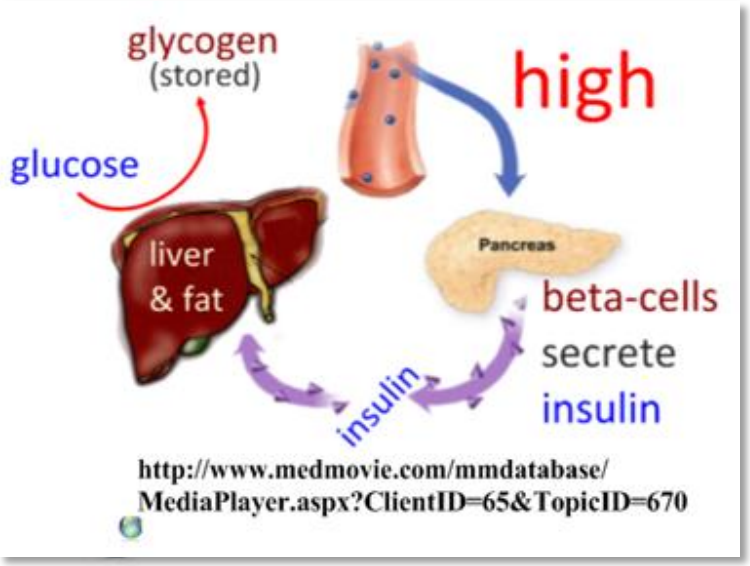
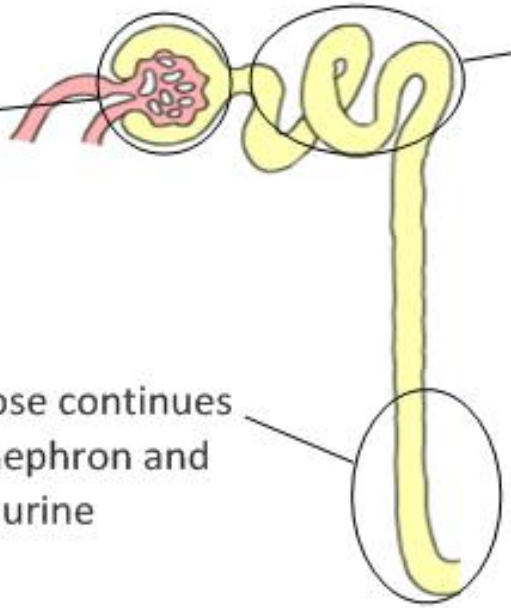


In the Kidney:

all glucose is passed into renal filtrate through ultrafiltration

there is too much glucose to be processed by selective reabsorption in the proximal convoluted tubule

so some glucose continues through the nephron and is excreted in urine

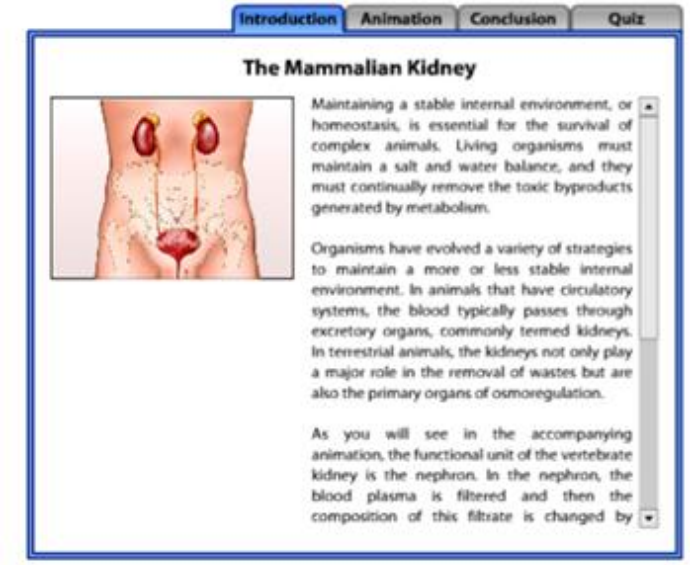


Kidney Resources:

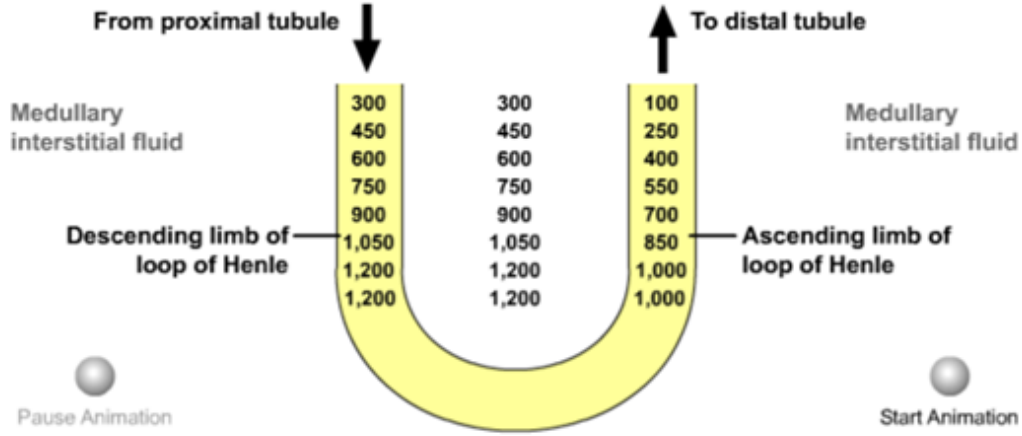
Formation of Urine (S4-5)

尿液的形成 (中四至中五)

http://cd1.edb.hkedcity.net/cd/science/biology/resources/animation/Topic16.swf



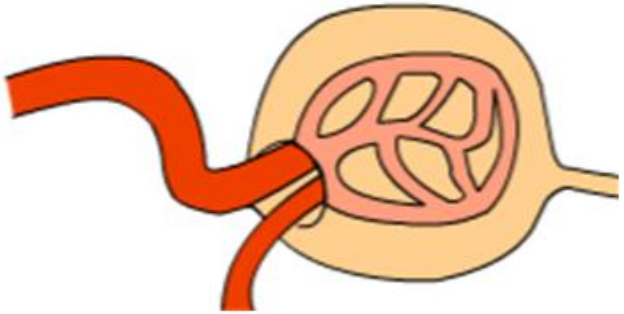
http://www.sumanasinc.com/webcontent/animations/content/kidney.html



The osmolarity of the renal medulla increases progressively from 300 mosm/liter at the boundary with the cortex to a maximum of 1,200 at the junction with the renal pelvis. **Click** START ANIMATION to learn how this gradient is established.

http://www.colorado.edu/intphys/Class/IPHY3430-200/countercurrent_ct.swf

http://www.zerobio.com/target_practice_quiz/target_practice_quiz_kidney.htm



For more IB Biology resources:

http://sciencevideos.wordpress.com