EXCRETORY SYSTEM

Content Statements:

D3.3.7 Role of the kidney in osmoregulation and excretion

D3.3.8 Role of the glomerulus, Bowman's capsule and proximal convoluted tubule in excretion

D3.3.9 Role of the loop of Henle

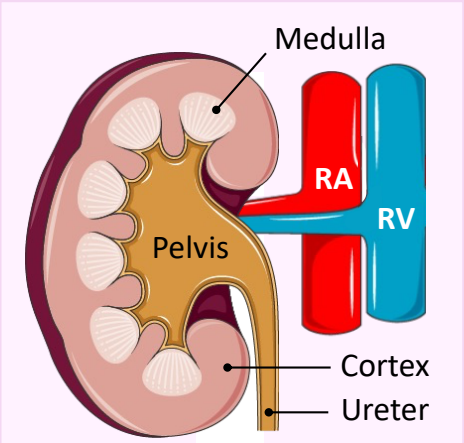
D3.3.10 Osmoregulation by water reabsorption in the collecting ducts

KIDNEYS

Kidneys are bean-shaped organs that function as a filtration system for the body by carrying out two vital and interconnected processes:

- **Excretion** – metabolic wastes (**urea**) are removed from the body
- **Osmoregulation** – control of the osmotic concentration (Osm/L)

Blood enters a kidney via the renal artery and exits via a renal vein. The blood is filtered within the kidney to produce **urine**, which will be transported via the ureter to be stored within the bladder, prior to excretion. The kidney is composed of an outer tissue layer called the **cortex**, which surrounds an inner tissue layer called the **medulla**.

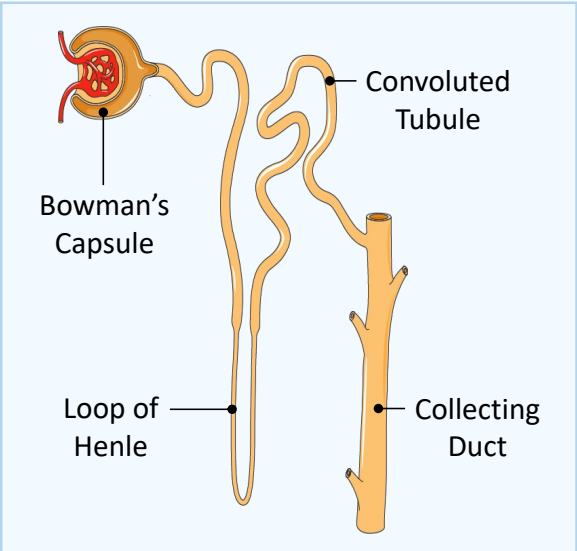


NEPHRONS

The nephron is the functional unit of the kidney, with each nephron being composed of the following 4 components:

- **Bowman's capsule** – interacts with blood (**glomerulus**)
- **Convoluted tubule** – the site of selective reabsorption
- **Loop of Henle** – establishes a salt gradient in medulla
- **Collecting duct** – feeds the urine into the renal pelvis

The Bowman's capsule and convoluted tubes are located within the cortex of the kidneys, while the loop of Henle and collecting duct descends into the medullary region. Multiple nephrons may share a single collecting duct and each kidney contains over a million nephrons on average.



BLOOD VERSUS URINE COMPOSITION

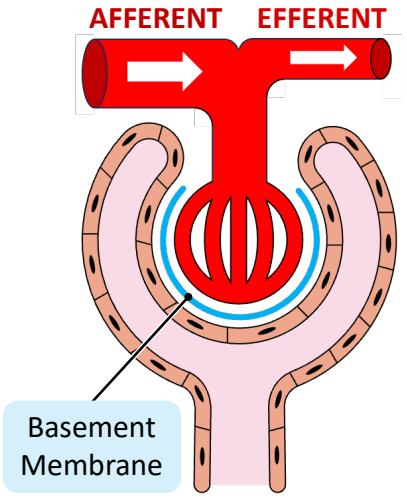
Blood is filtered within the kidneys to form **filtrate**, which is then converted into urine for elimination from the body. All blood cells and large proteins are retained within the plasma, while nutrients such as glucose, amino acids, vitamins and ions are all reabsorbed. This means that only urea and variable levels of water will remain in the urine. The presence of other material may indicate **disease** (e.g. the presence of glucose in urine is an indicator of diabetes) and urine can be tested for the presence of certain types of **drugs**.

	Blood	Filtrate	Urine
Cells	✓	✗	✗
Protein	✓	✗	✗
Glucose	✓	✓	✗
Urea	✓	✓	✓
Water	✓	✓	✓

EXCRETION

There are two key processes involved in the excretion of wastes – ultrafiltration and selective reabsorption.

Ultrafiltration



As blood moves into a kidney via afferent arterioles, it enters a knot-like capillary tuft called the glomerulus. Each glomerulus is surrounded by a **basement membrane** and encapsulated within a Bowman's capsule. The glomerulus is fenestrated (porous), while the cells lining the capsule are interdigitated with narrow spaces between them. This means fluid can freely move from blood to the nephron, with the basement membrane acting as the sole filtration barrier (blood cells and plasma proteins will not pass). Kidneys increase the hydrostatic pressure in the glomerulus by having wider afferent arterioles (leading in) and narrower efferent arterioles (leading away). This pressure forces fluid into the nephrons.

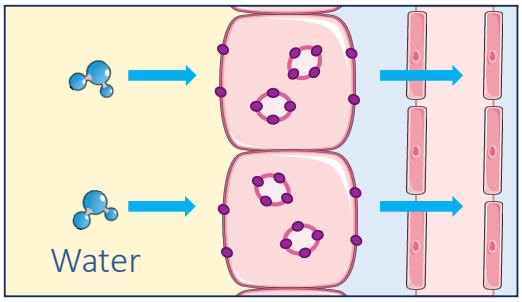
Selective Reabsorption

As filtrate moves along the proximal convoluted tubule, useful substances are selectively reabsorbed back into the bloodstream. The tubule is convoluted to increase surface area and the cells lining the tubule wall contain **microvilli** to optimise material absorption. Tubule cells are connected by **tight junctions** (no gaps) and each tubule cell has a large number of **mitochondria** to support active transport. Materials selectively reabsorbed include glucose and amino acids (cotransport with sodium), mineral ions and vitamins (active transport or facilitated diffusion) and water (osmosis). Urea and toxins remain in the filtrate for excretion.

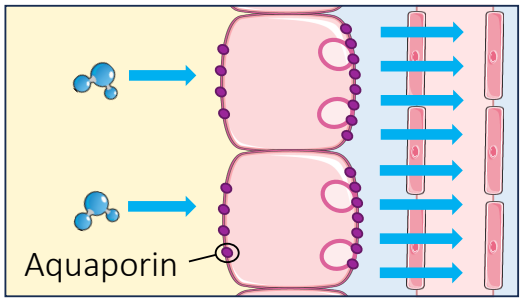
OSMOREGULATION

Osmoregulation is the control of the osmotic concentration of the tissues and blood. It is mediated by the loop of Henle and the collecting duct. The loop of Henle functions to create a high osmotic concentration in the tissue fluid of the medulla. The **ascending limb** of the loop of Henle is embedded with ion pumps that actively transport **sodium ions** into the medulla to create a **hypertonic solution**. Creating a salt gradient in the medulla will allow water to be drawn out of the collecting ducts (via osmosis) and retained by the body.

The amount of water released from the collecting duct is controlled by **antidiuretic hormone** (ADH). ADH is released from the posterior pituitary gland in response to dehydration (which is detected by osmoreceptors in the hypothalamus). ADH will increase the permeability of the collecting duct to water, by causing vesicles containing **aquaporins** to fuse with the membrane of the cells lining the collecting duct. This increases the amount of aquaporins lining the collecting duct, meaning more water is reabsorbed into the bloodstream. This means that less water remains in the filtrate and the urine becomes more concentrated. The levels of ADH will decrease when a person is suitably hydrated, resulting in less reabsorption and more dilute urine.



LOW ADH = LOW REUPTAKE



HIGH ADH = HIGH REUPTAKE