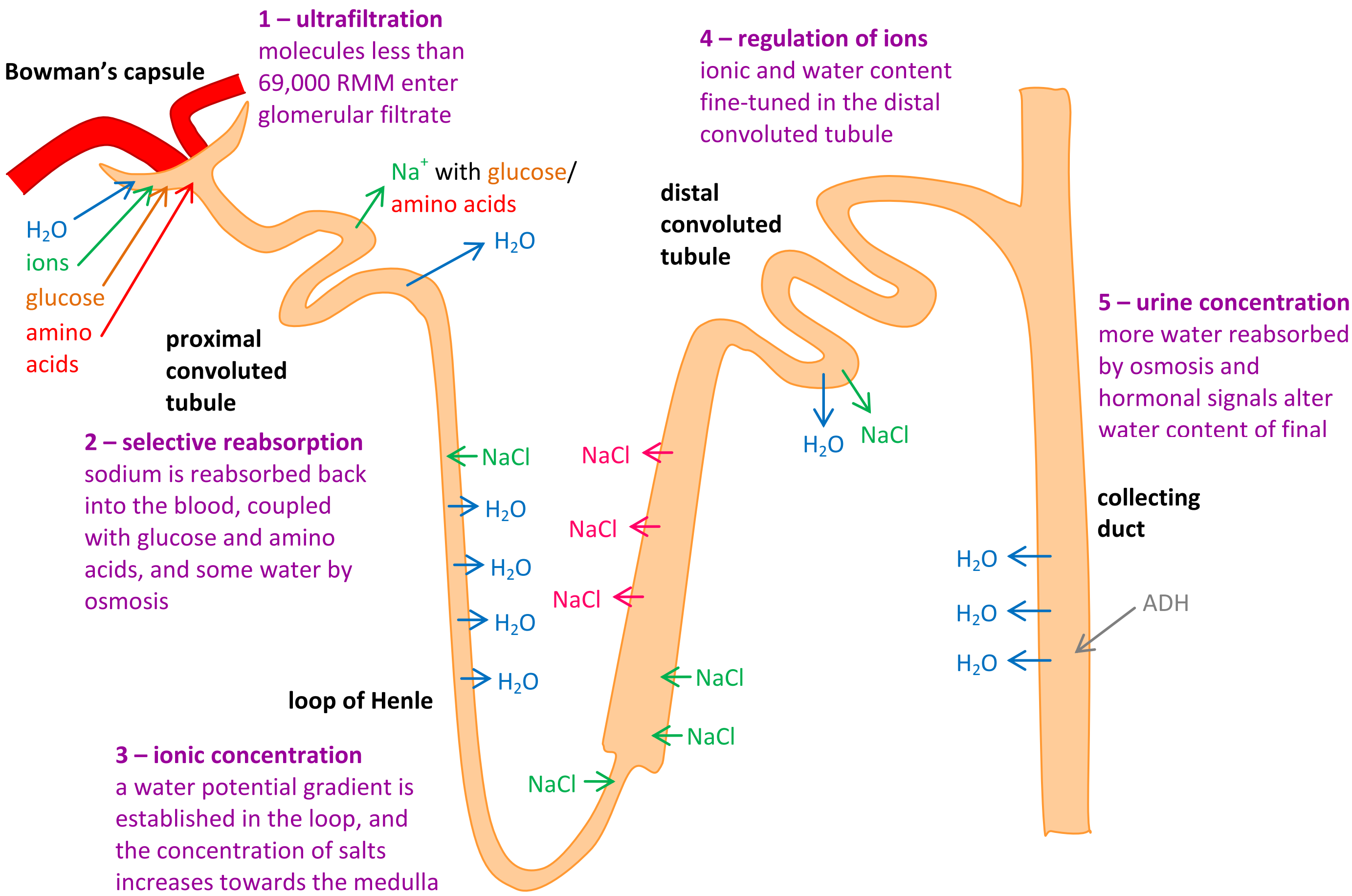
2.4 Osmoregulation

Regulating the water concentration of the nephric filtrate, urine and bloodstream

What happens in the nephron?

You will have seen in the previous unit, 2.3 The kidney, how the different processes which occur at different points in the nephron result in the formation of **urine**. The diagram below shows a complete nephron, and briefly explains the processes which occur at each stage. The various substances which enter and leave the tubule filtrate are also shown.



ADH and the brain

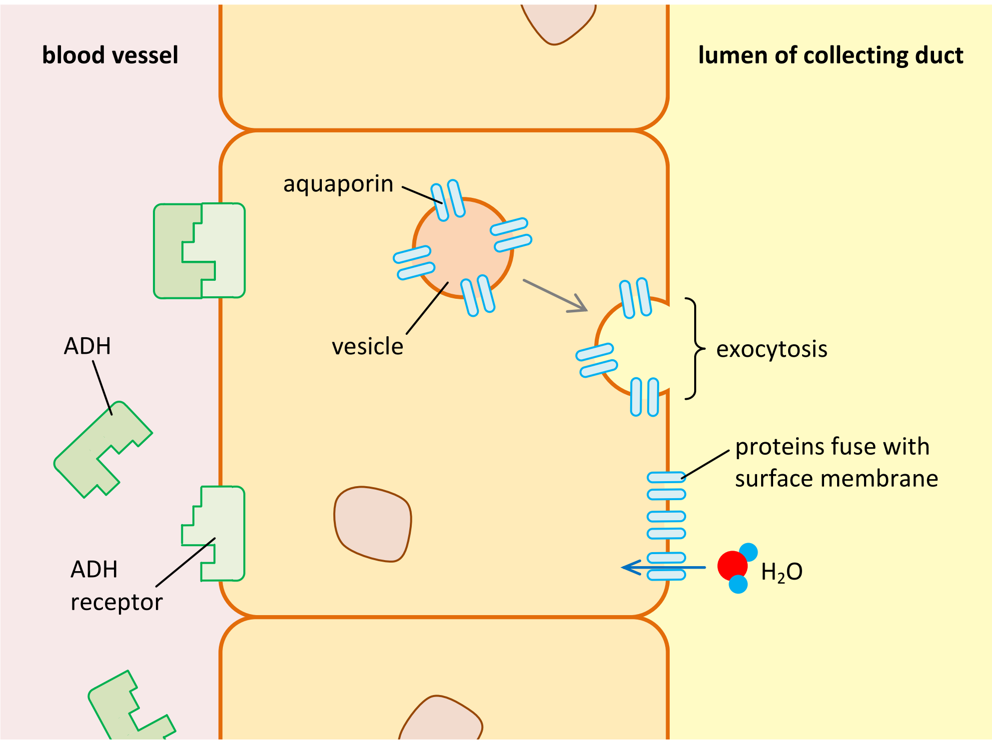
There is a **water potential gradient** down the collecting duct to the medullary tissue of the kidney. This causes water to move out of the collecting duct by osmosis. Water reabsorption in the collecting duct like this is controlled by the levels of **ADH** (antidiuretic hormone) in the blood vessels in contact with the walls of the collecting duct. ADH is a hormone which in larger amounts will cause more water to be absorbed, and so urine is more concentrated and less urine is released.

The water potential of the blood is detected by sensory cells called **osmoreceptors** in a region of the brain called the **hypothalamus**, which you will be familiar with from thermoregulation, as well as other functions. Normal osmosis rules apply to these cells, as in when the water potential of the blood is *low*, water will move out of osmoreceptors by osmosis (because the cells will have a higher water potential, and water always moves down the potential gradient), causing the cells to shrivel – and so more ADH is released (which will ultimately increased the water potential of the blood, as ADH will make the collecting duct walls more permeable to water so more will be reabsorbed).

When the osmoreceptors shrink due to a lower water potential, they stimulate **neurosecretory cells** in the hypothalamus to manufacture and release ADH. When ADH is made, it travels down the axon of the cell it is made in (ADH is produced in the cell body), and is stored in the **posterior pituitary gland** until needed. When the neurosecretory cells have been stimulated, the ADH is released into the bloodstream by the posterior pituitary gland.

The collecting duct

There are receptors for the ADH hormone amongst the cells which line the walls of the collecting duct. These cells contain numerous vesicles which contain nothing except cellular fluid, but they do hold protein channels which are permeable to water, called **aquaporins**.



When ADH binds to its receptor on such a cell, a series of enzyme-controlled reactions are triggered. Ultimately, this causes the vesicles to fuse with the cell surface membrane in contact with the lumen of the collecting duct. This places the aquaporin channels on the cell membrane, so that water can move into the cells through the channel, as the walls become more permeable to water.

When there is more ADH in the blood, more ADH will bind to receptors (forming *enzyme-substrate complexes*) which will make the walls of the collecting duct even more permeable to water, and so more will be reabsorbed. Therefore, urine is of a lower water potential and less of it passes out of the body.

However, when there is less ADH in the blood, the cells stop placing aquaporins in the plasma membrane. In fact, the cell actually folds inwards to produce extra vesicles which remove aquaporins from the membrane, so that even less water is reabsorbed. This in turn, makes the urine less concentrated and has a higher water potential, and more will be produced.

Water reabsorption in the nephron

Water is a very small molecule, and so all water enters the glomerular filtrate during *ultrafiltration* at the glomerulus and renal capsule. During selective reabsorption, the movement of sodium coupled with glucose and amino acids out of the convoluted tubule creates a water potential gradient, and so water moves out of the tubule. So water begins getting reabsorbed back into the blood at the proximal convoluted tubule, during selective reabsorption.

The function of the loop of Henle is to reabsorb water from the filtrate, as there is still around 40% of the water remaining in the filtrate. Nephrons appear differently in different animals. For example, those which live in dry conditions have much longer loops of Henle, because clearly the longer the loop, the more water is reabsorbed back into the blood. A fantastic example is the *kangaroo rat*, which has a very long loop of Henle, which is capable of reabsorbing much more water from the nephric filtrate. In fact, the urine is so concentrated due to the removal of such an extraordinary amount of water, that it has a concentration of 6,000mOsM/litre. This is five times as efficient as in humans, where the concentration is at 1,200mOsM/litre. Due to this feature, the kangaroo rat never has to drink, because it can obtain all of the water it needs from its metabolism.

After the proximal convoluted tubule and the loop of Henle, further water is lost at the distal convoluted tubule, and reabsorbed back into the blood. This is more of a fine-tuning, where the concentrations are tweaked – not a significant change in concentration. And of course, finally water is reabsorbed from the collecting duct, dependent upon the levels of the hormone ADH present in the bloodstream.

Concentrations of substances in nephric filtrate

The table on the following page displays the presence of each substance along the different sections of a nephron.

	Renal capsule (glomerular filtrate)	Proximal convoluted tubule	Loop of Henle	Distal convoluted tubule	Collecting duct	Urine
glucose	✓	reabsorbed	**not present in filtrate**			
amino acids	✓	reabsorbed	**not present in filtrate**			
proteins	✗ (only small proteins)	**not present in filtrate**				
water	✓	60% reabsorbed	much reabsorption	more reabsorbed	possible further reabsorption	✓ (small amounts)
urea	✓	✓	✓	✓	✓	✓
ions	✓	partially reabsorbed	mostly reabsorbed	final reabsorption	**not present in filtrate**	

But how does the concentration of each substance differ at each component of the nephron? The graph below outlines the changing concentrations of water, urea, glucose and ions at each part of the nephron.