PARTNERSHIP IN CRITICAL CARE DEPT. WAIKATO

CRITICAL CARE WAIKATO HOSPITAL

WORKBOOK

NAME: _____

Te Hanga Whaioranga Mō Te Iwi
Building Healthy Communities

Waikato District Health Board

Section one

Anatomy and physiology of the renal system

1.1 Functions of the kidney

The kidneys play a dominant role in filtration and a minor role in metabolism. They receive 21% of cardiac output, equating to 1.2 litres of blood per minute. The entire blood volume is filtered by the kidneys 340 times per day (Morton & Fontaine, 2013).

Its main functions include:

- Regulation and maintenance of the concentration of solutes in the extracellular fluid (ECF).
- Removal of metabolic waste products
- Maintenance of blood pressure
- Regulation of fluid balance and pH control

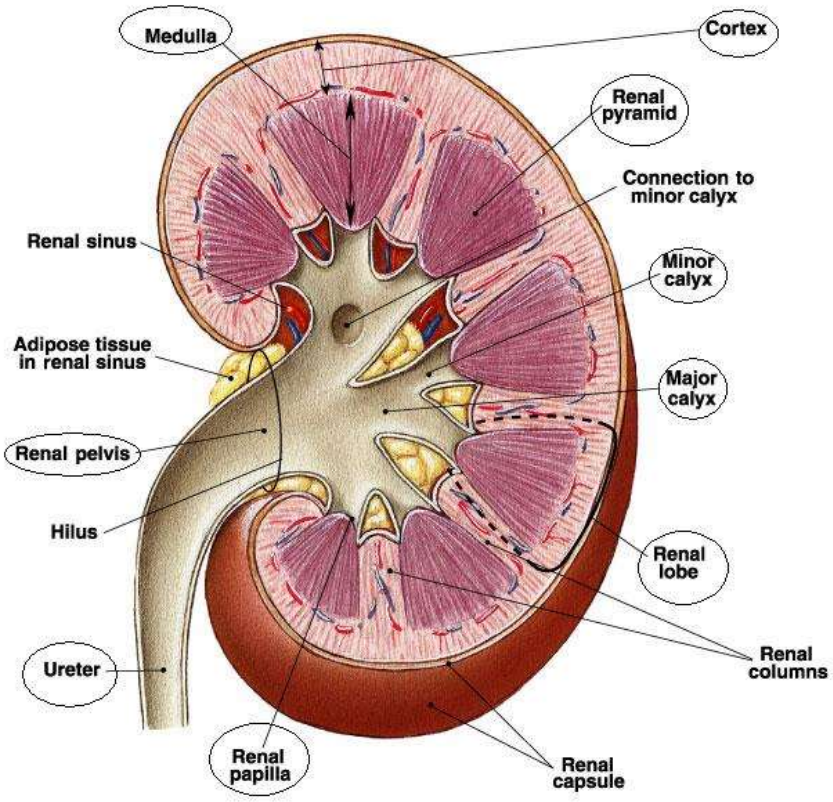


Fig.1. Anatomy of the kidney
(Google images, July 2013, author not found)

Other important renal functions are:

- Manufacture of hormones;
    - **calcitriol** - increases intestinal absorption of calcium, also promotes bone reabsorption and tubular reabsorption of calcium
    - **Erythropoietin** – stimulates the bone marrow to produce red cells. The kidney initiates the release of erythropoietin in response to sensed decreases in pO_2 content.

- Activation of **vitamin D**. Vitamin D is ingested in inert form with food. The kidney activates it and it then also has a role in calcium reabsorption from the gut. **Nb:** decreased vitamin D levels occurring in renal failure make the patient more prone to bone disease and bleeding issues.

1.2 Anatomy

The kidneys are bean shaped and lie in a retroperitoneal position in the abdomen, one on each side. The right kidney sits slightly lower than the left due to the position of the liver. The adrenal glands cap the apex of the kidneys. They are approx 12cm long, 6cm wide and 2.5 cm thick. They weigh approx 150g each and are each the size of a clenched fist.

They consist of 2 layers, the renal cortex and the renal medulla (Fig.1).

Renal cortex: The outer portion of the kidney - contains the glomeruli, the proximal tubules, the cortical loops of Henle, the distal tubules and the cortical collecting ducts. The cortex receives 90% of renal blood flow.

Renal medulla: The inner layer - contains the renal pyramids (in addition to cortical structures). These pyramids contain the medullary portions of the loops of Henle and collecting ducts. The collecting ducts join to form a minor calyx, which with other calyces collectively form a major calyx. The renal medulla receives only 5-10% of renal blood flow.

The major calyces join together to direct urine into the **ureter**. The action of peristalsis facilitates the flow of urine into the bladder. The ureter along with the renal arteries, veins and nerves exit or enter the kidney at a medial indentation called the **hilum.**

The renal artery divides into smaller branches and then into tufts of afferent capillaries known as the **glomerulus**, where blood is filtered.

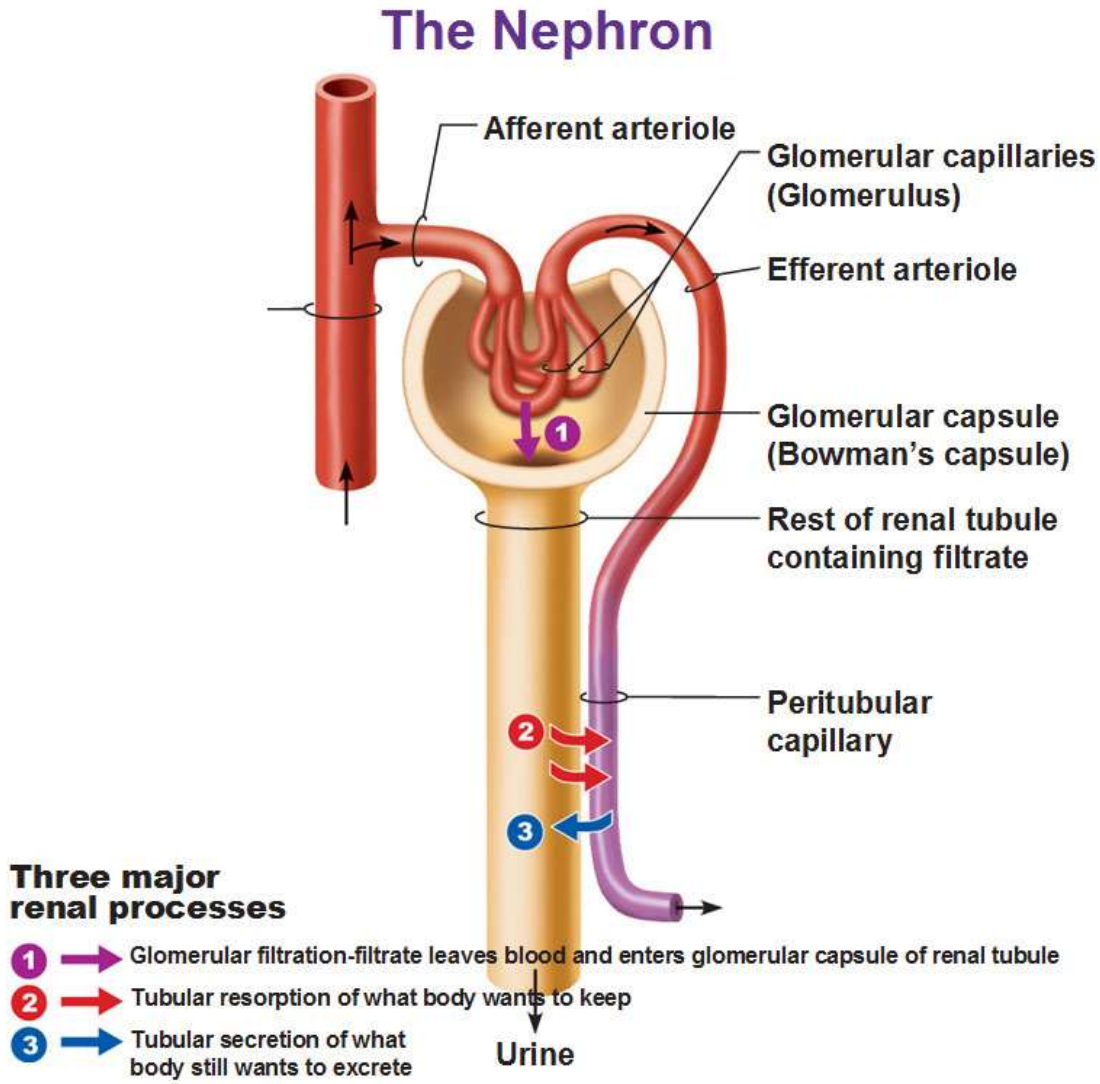


Fig.2. The Nephron (Google images, 2013. Author not found)

The **glomerulus** is surrounded by the **Bowman's capsule** into which urine is filtrated from the capillaries. Lower hydrostatic pressure in the efferent (outgoing) capillaries allows for reabsorption to take place. Filtration is determined by net filtration pressure. The rate at which filtrate is formed is termed the glomerular filtration rate (GFR). Approximately 125mls/min of filtrate is formed.

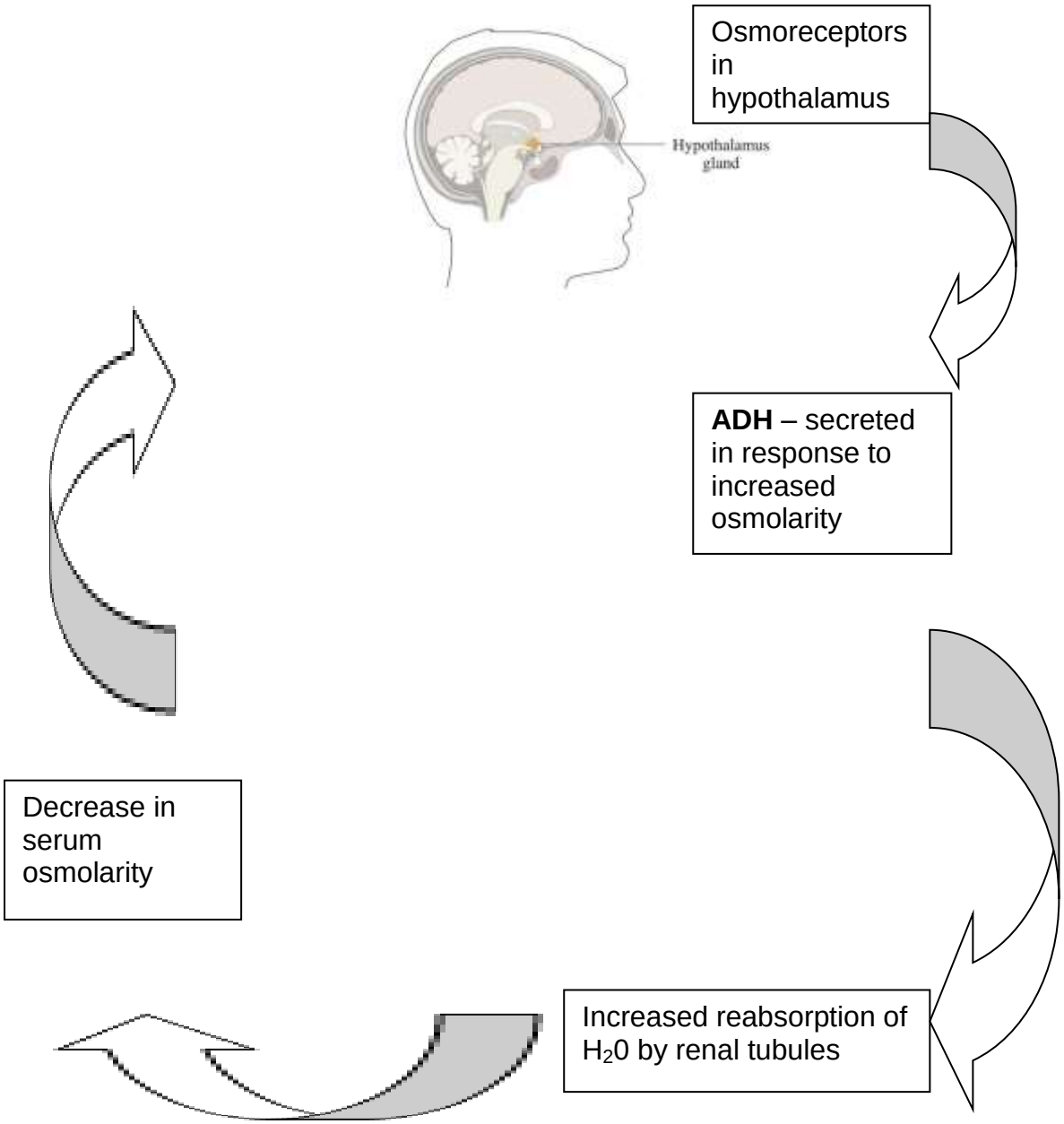
Tubular reabsorption occurs in all parts of the nephron as substances move from the lumen to the peritubular capillaries. Diffusion, osmosis, and active transport processes occur. The active transport of Na+ is responsible for the osmotic reabsorption of water.

Tubular secretion is on the other hand only by active transport, and occurs in the distal tubules. In this process waste products are secreted out of the capillaries and into the tubules, to be excreted in the urine. Some substances that occur naturally in the body are secreted (e.g. hydrogen ions), along with some that do not occur naturally (e.g. drugs or drug metabolites). The active transport of Na+ as it is reabsorbed is linked to the secretion of K+ and H+. For every Na+ ion reabsorbed either hydrogen (H+) or potassium ion (K+) must be secreted. The choice of which is excreted will depend on extracellular concentrations of each.

The final regulation of urine concentration is influenced by hormonal control. The hormones involved are anti-diuretic hormone (ADH), renin, and aldosterone.

Anti-diuretic Hormone (ADH)

When a patient is dehydrated serum osmolarity will rise. Osmoreceptors in the hypothalamus are sensitive to these changes in osmolarity and stimulate the hypothalamus to secrete ADH, which increases the permeability of the collecting tubules to H_2O. H_2O alone is reabsorbed without electrolytes, decreasing the concentration of extra-cellular fluid (ECF). A negative feedback loop then regulates ADH secretion, as its stimulus disappears.



Renin

Renin is secreted by the juxtaglomerula apparatus (located in the nephron afferent and efferent circulation) in response to decreased glomerular filtration rate (GFR) (see diagram 28.4, Morton and Fontaine, 2013).

Decreased levels of Na+ will also stimulate secretion of renin. Renin converts angiotensin (manufactured in the liver) into angiotensin I. This is further converted by the pulmonary capillary cells into angiotensin II, utilising the angiotensin converting enzyme (ACE). – (see fig. 42.9, Ch 42, Morton & Fontaine, 2013). Angiotensin II constricts the smooth muscle surrounding the arterioles, in order to increase blood pressure and thereby increase GFR.

Aldosterone

Angiotensin II also triggers the secretion of aldosterone by the adrenal cortex (see fig. 42.9, Ch 42, Morton& Fontaine, 2013). Aldosterone increases Na+ reabsorption in distal tubules. This causes an increase in H_2O reabsorption. K+ is secreted at the same time as Na+ is reabsorbed (i.e. they are exchanged). Aldosterone is also secreted in response to high K+ levels
(Morton & Fontaine, 2013).

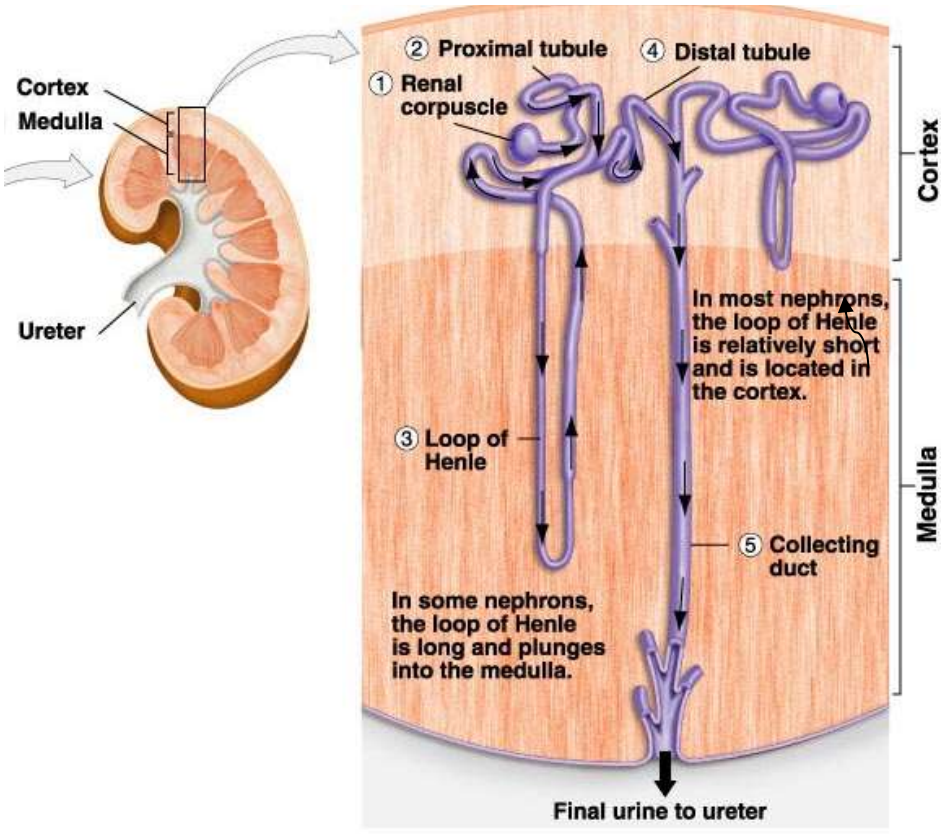


Fig 3. The Loop of Henle (Google Images, 2013. Author not found)

Nb: The distal tubule from several nephrons drains in to one single collecting duct. There are about 250 large collecting ducts for about 4000 nephrons (Gambro 2004).

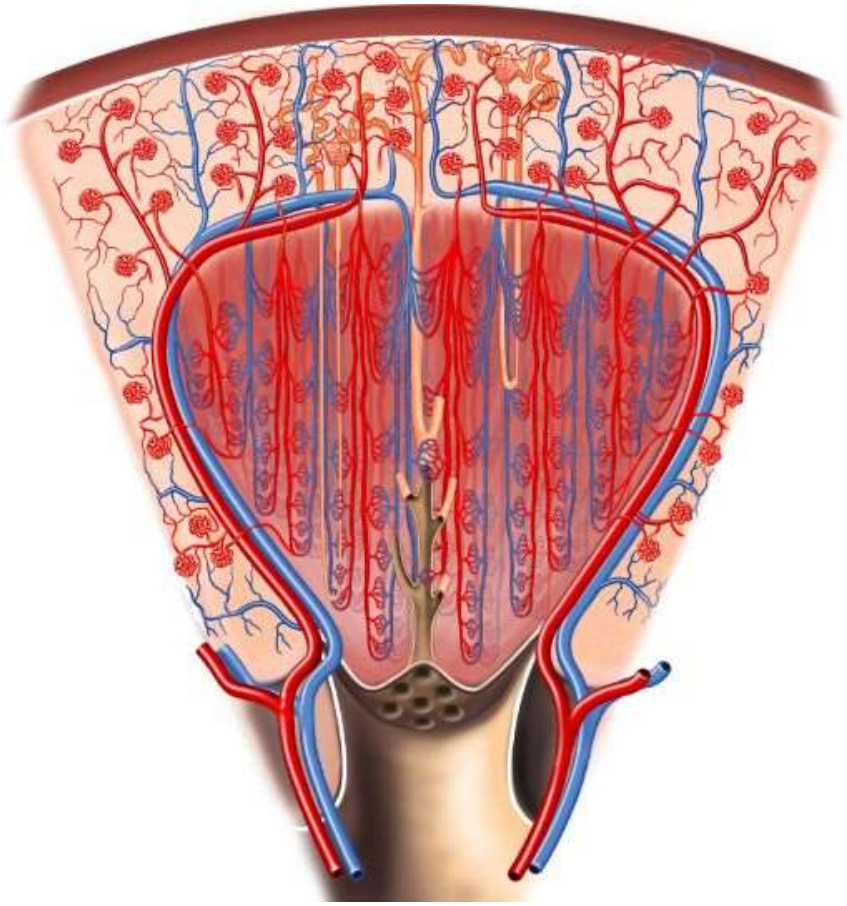


Fig.4 The renal pyramid – (Radius Medical Illustration, 2013).

Required reading

Morton, P and Fontaine, D. (2013). *Critical care nursing: a holistic approach*. 10th ed. Lippincott, Williams & Wilkins: Philadelphia. Read Chapter 28

Additional reading

Gambro (2004). The Kidney: Renal Intensive care Self Directed Module. Version 1, Gambro Lundia AB.

References

Morton, P and Fontaine, D. (2013). *Critical care nursing: a holistic approach*. 10th ed. Lippincott, Williams & Wilkins: Philadelphia. Read pages

Gambro (2004). The Kidney: Renal Intensive care Self Directed Module. Version 1, Gambro Lundia AB.

Acknowledgements

Smartsite images and Radius Medical Illustrations have kindly provided many of the images utilised in this module. Alternate images have been accessed via google images.