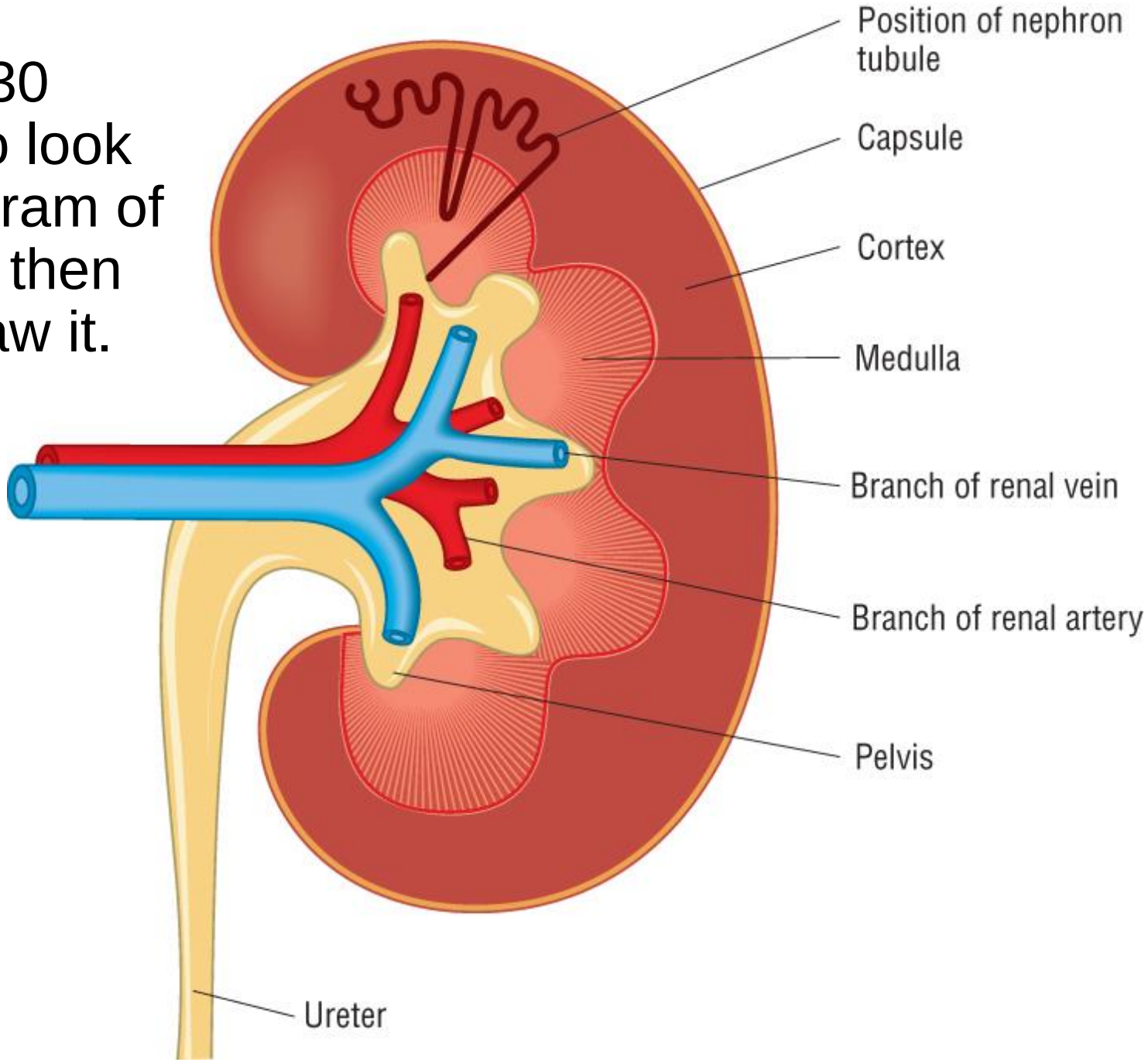
The Kidney

- Describe, the histology and gross structure of the kidney.
- Describe the detailed structure of a nephron and its associated blood vessels.
- Describe and explain the production of urine, with reference to the processes of ultrafiltration and selective reabsorption.
- Explain, using water potential terminology, the control of the water content of the blood, with reference to the roles of the kidney, osmoreceptors in the hypothalamus, and the posterior pituitary gland.
- Outline the problems that arise from kidney failure and discuss the use of renal dialysis and transplants for the treatment of kidney failure.
- Describe how urine samples can be used to test for pregnancy and to detect the misuse of anabolic steroids.

You have 30 seconds to look at the diagram of a kidney – then try to redraw it.



Kidney Structure

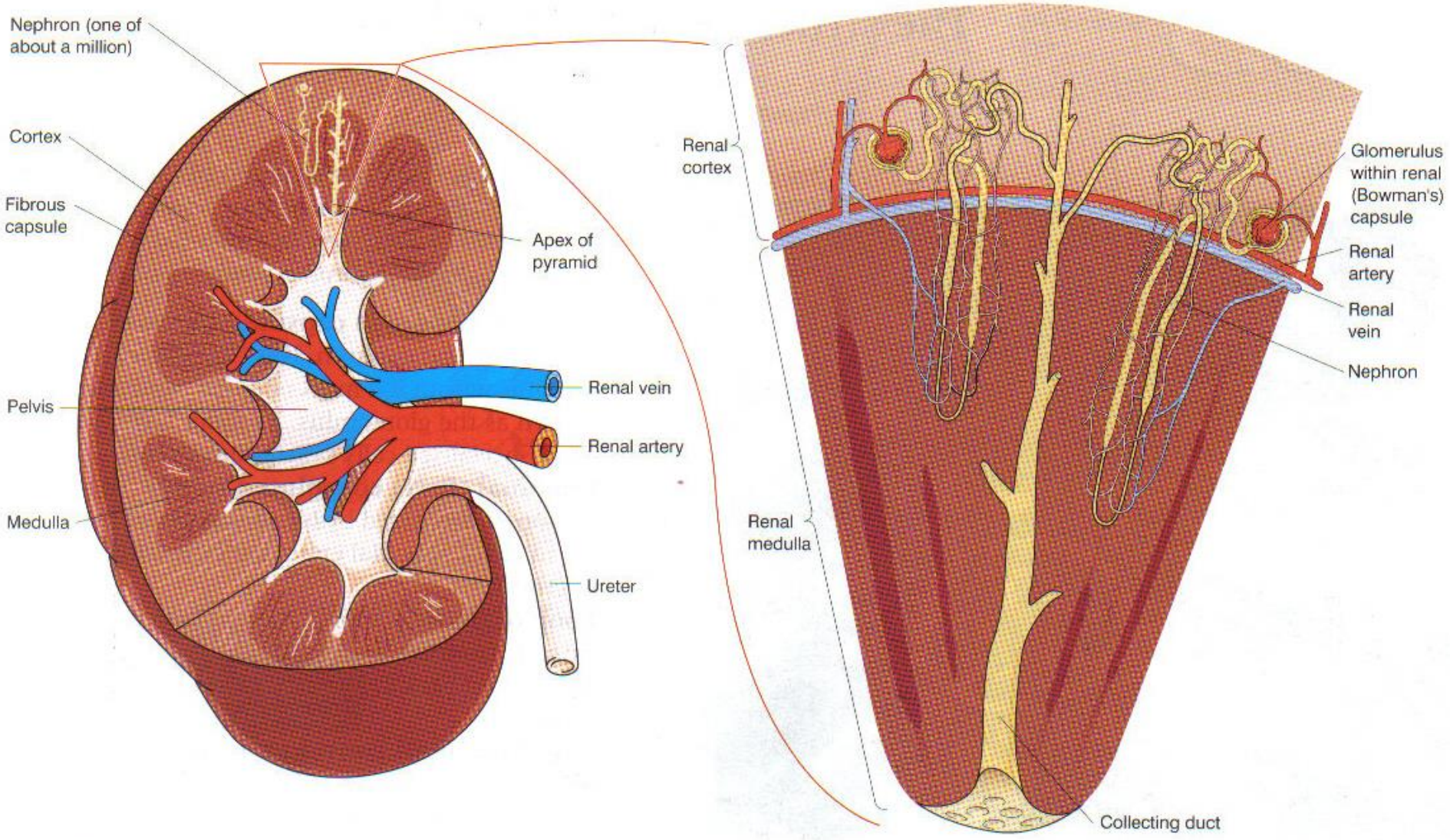


Fig 6.4 *Detailed structure of mammalian kidney (LS) showing the position of two of the million or more nephrons in each kidney*

A Nephron.

The functional unit of the kidney.

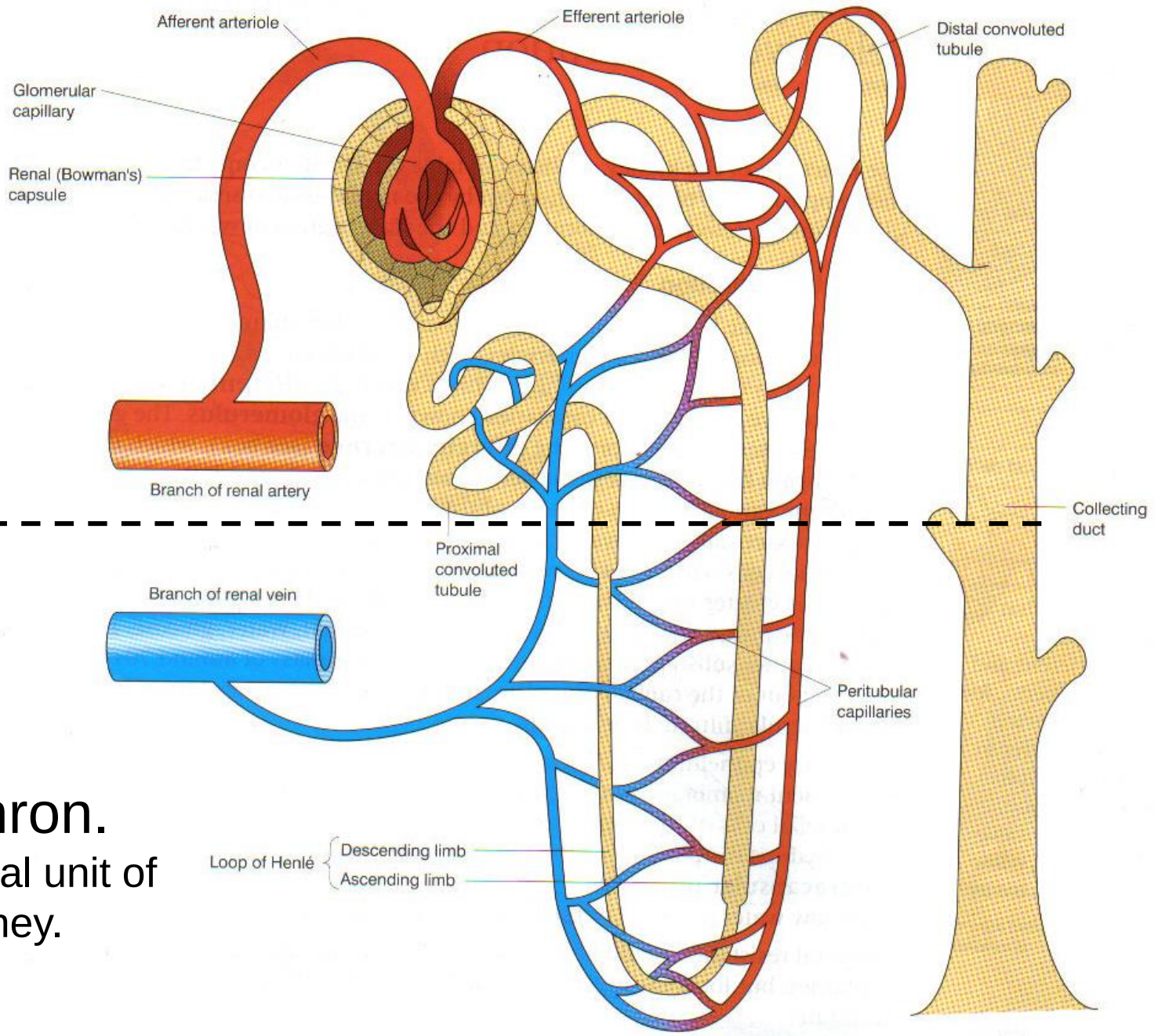


Fig 6.5 *Regions of the nephron and associated blood vessels*

Ultrafiltration.

Removal of most of the blood plasma.

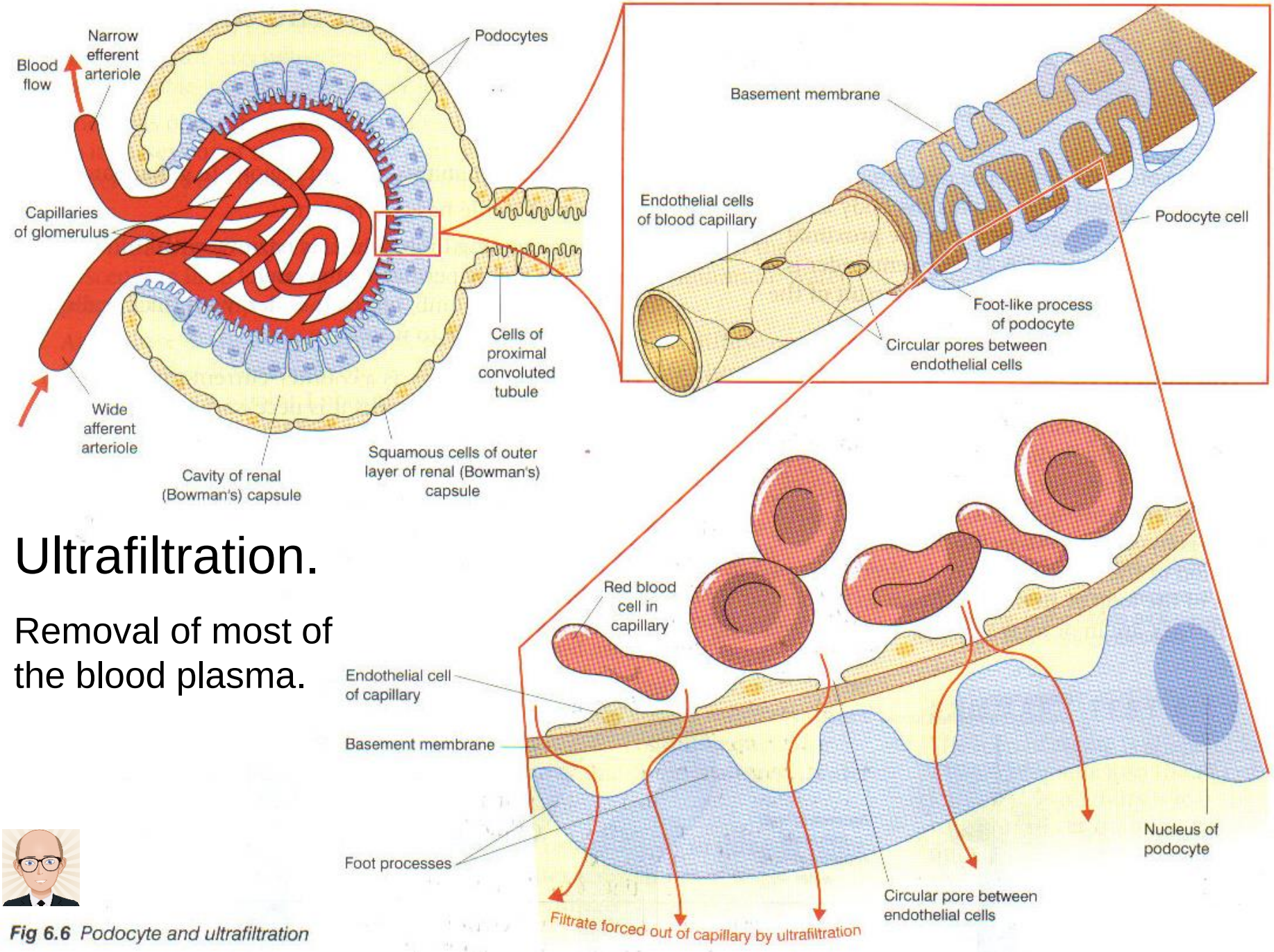


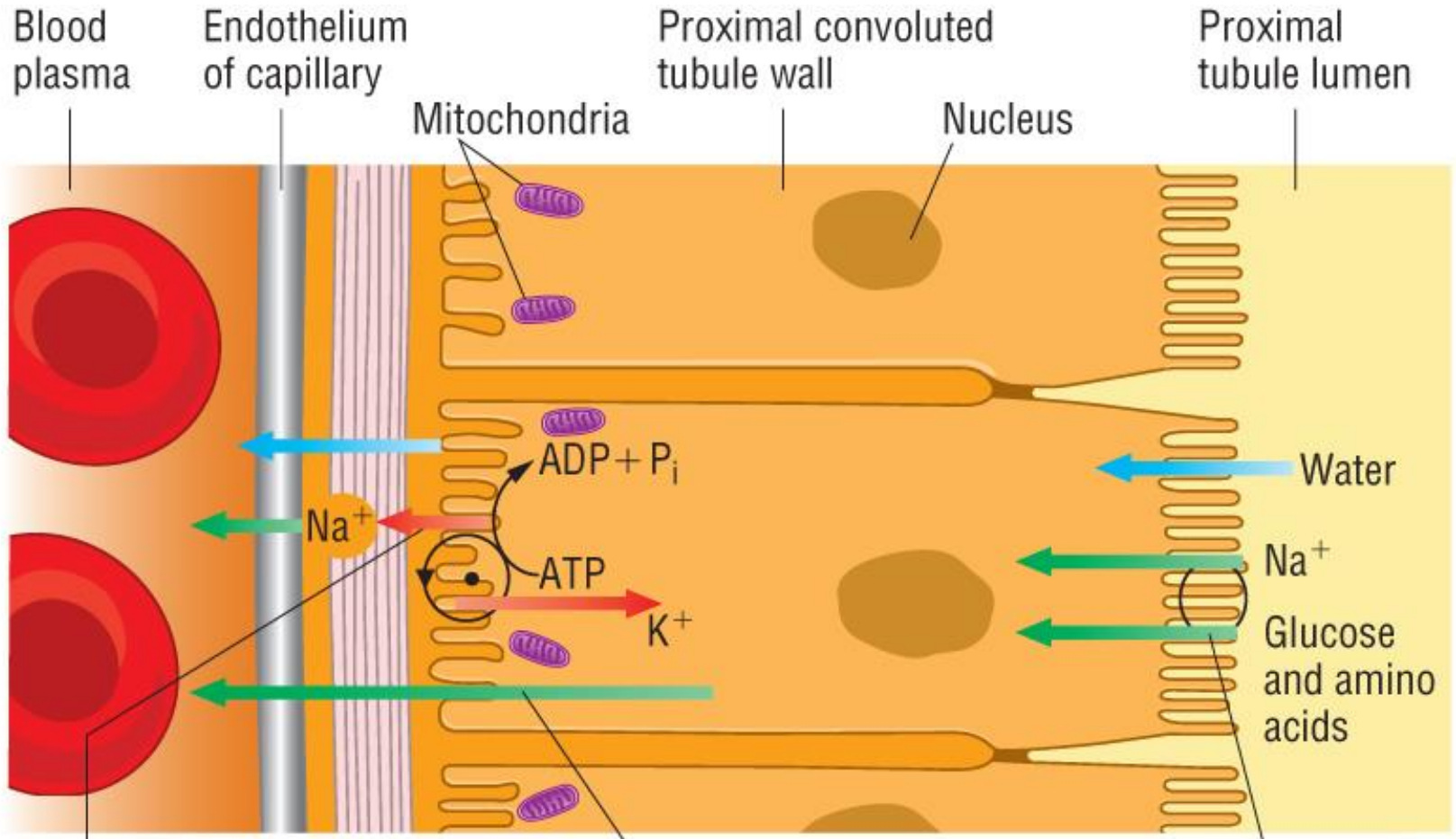
Fig 6.6 *Podocyte and ultrafiltration*

Selective Reabsorption

- In the proximal convoluted tubule, almost 85% of filtrate is reabsorbed back into the blood.
  - Most of it is useful to the body.

- So why remove it in the first place?
  - When clearing out a drawer it is often easier to empty the lot & only put back what you need rather than pick out the unwanted items.

How is it reabsorbed?



Summary Test

The [1] is the structural unit of the kidney. It comprises a cup shaped structure called the [2] which receives blood from a vessel called the [3] arteriole. The [4] arteriole is [5] in diameter than the [3] which creates a large hydrostatic pressure within the vessel. Substances with a RMM of below 70,000 are squeezed out through [6] between the endothelial cells of the capillary and between specialised cells called [7] into the cavity of the [2]. The filtrate passes along the [8] convoluted tubule where 85% of it is reabsorbed back into the blood. Glucose & amino acids enter the tubule epithelial cells by a process called [9] and may be pumped out into the space around the capillaries by [10]. From here they [11] back into the blood. Water is reabsorbed by [12] as a result of [13] ions being pumped into the space around the capillaries.

Test Answers

1. Nephron
2. Bowman's Capsule
3. Afferent
4. Efferent
5. Smaller
6. Pores
7. Podocytes
8. Proximal
9. Facilitated diffusion
10. Active transport
11. Diffuse
12. Osmosis
13. Sodium

The Function of the Loop of Henlé

- A hairpin shaped tubule extending into the medulla.
- Responsible for reabsorbing water from the collecting duct.
- Its length is responsible for the concentration of urine produced.
  - It is short in mammals living by water (beavers) & long in desert mammals.

The Structure of the Loop of Henlé

- Two regions:
  - Descending limb.
    - Narrow
    - Thin walls
    - Walls permeable to water
  - Ascending limb.
    - Wider
    - Thick walls
    - Walls impermeable to water

Filtrate from PCT
Distal convoluted tubule
Cortex
Medulla
Descending limb
Interstitial Region
Ascending limb
Collecting duct
Urine

Filtrate from PCT
Cortex
Medulla
Na+
Cl-
H2O
H2O
Cl-
Na+
H2O
H2O
Low Ψ
High Ψ
H2O
H2O
H2O
H2O
H2O
H2O
H2O
H2O
Low Ψ
Urine

Summary Test

The loop of Henlé is shaped like a [1] & extends into the [2] of the kidney. Although its role is to reabsorb water from the collecting duct, most water is actually reabsorbed into the blood from the [3]. The loop of Henlé has a descending and an ascending limb. The [4] limb has thinner walls. The [5] limb is much more permeable to water. The loop of Henlé operates by pumping Na^+ & Cl^- ions out of the [6] limb, creating a [7] water potential in the interstitial region. As a result, water is drawn out of the descending limb by [8] & passes into the blood capillaries by the same process. The distal convoluted tubule makes final adjustments to the salt content of the filtrate & controls the [9] of the blood. As the filtrate flows into the collecting duct, the decreasing water potential of the surrounding medulla ensures that water is reabsorbed along the entire length of the duct. This water passes through channels & is under the control of the hormone [10].

Test Answers

1. Hairpin
2. Medulla
3. Proximal convoluted tubule
4. Descending
5. Descending
6. Ascending
7. Lower
8. Osmosis
9. pH
10. Antidiuretic Hormone (ADH)

Control of water & solutes in the blood.

- Blood needs a constant level of water & solutes.
  - Avoids osmotic problems in cells.

- Osmoregulation occurs by hormones acting on the walls of the collecting duct.
  - The amount of water reabsorbed from the DCT is determined by the permeability of DCT walls to water.

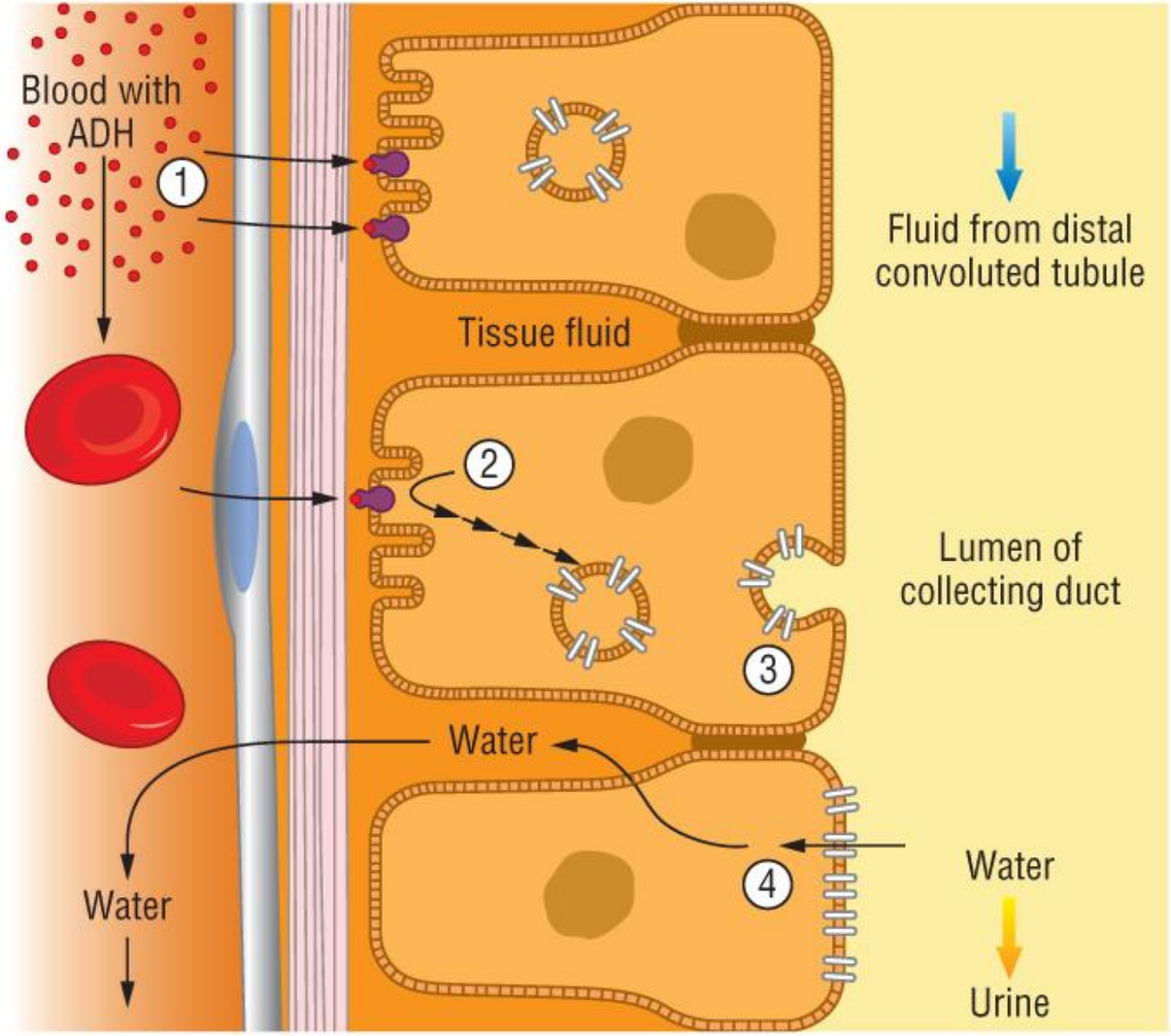
Osmoregulation

- Control of blood water potential.
- The walls of the collecting duct can become more or less permeable to water.

ADH

- The walls of the collecting duct respond to Antidiuretic Hormone (ADH).

- ADH causes water permeable channels to be inserted into the membrane of these cells.
  - This makes the walls more permeable to water, allowing more water to be reabsorbed.
    - Urine is therefore of a lower water potential and there is less of it.

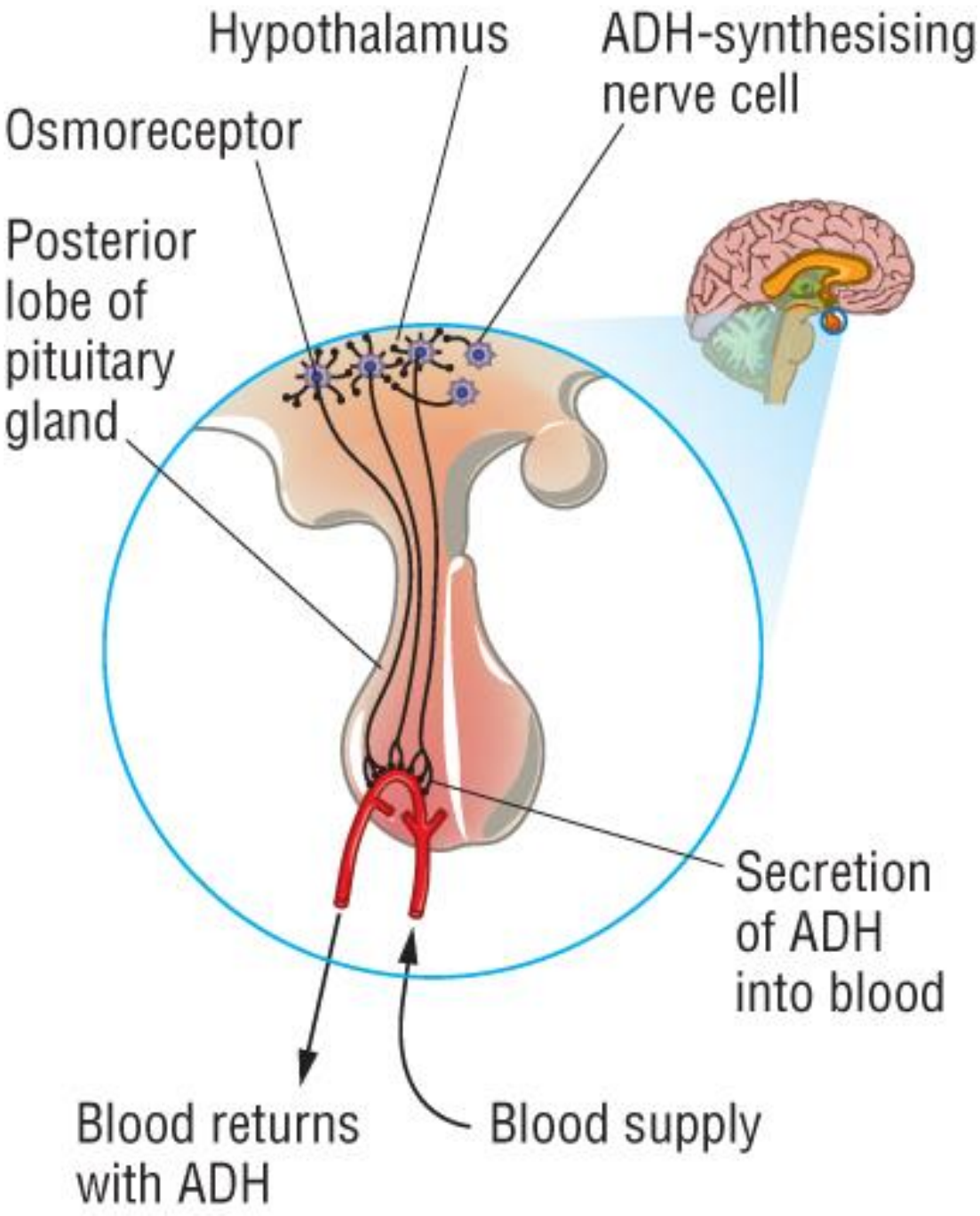


1. ADH detected by cell surface receptors
2. Enzyme-controlled reactions
3. Vesicles containing water-permeable channels (aquaporins) fuse to membrane
4. More water can be reabsorbed

Control of ADH

- Blood water potential is monitored by osmoreceptors in the hypothalamus.
  - These stimulate neurosecretory cells in the hypothalamus when blood water potential is low.

- Neurosecretory cells are nerve cells that also secrete ADH.


Hypothalamus
ADH-synthesising nerve cell
Osmoreceptor
Posterior lobe of pituitary gland
Secretion of ADH into blood
Blood returns with ADH
Blood supply

Detected by osmoreceptors in hypothalamus

Pituitary gland releases MORE ADH

Walls of DCT & CD become MORE permeable to water

Less water leaves the body. Urine is concentrated

Conserving water

Stimulate thirst centre of brain

More water consumed

Gaining water

Decreased water potential of blood

Normal blood water potential

More water leaves the body. Urine is Dilute

Removing water

Increased water potential of blood

Walls of DCT & CD become LESS permeable to water

Pituitary gland releases LESS ADH

Detected by osmoreceptors in hypothalamus

Drugs

- Alcohol inhibits ADH production.
- Caffeine inhibits reabsorption of Na+ in PCT.
- What are the effects of these?

Kidney Failure

- Common causes:
  - Diabetes mellitus
  - Hypertension
  - Infection

- Effects:
  - Inability to regulate blood water potential
  - Inability to remove urea & excess salts
  - Death

Treatment of Kidney Failure

- Two main treatments:
  - Dialysis
  - Transplant

Dialysis

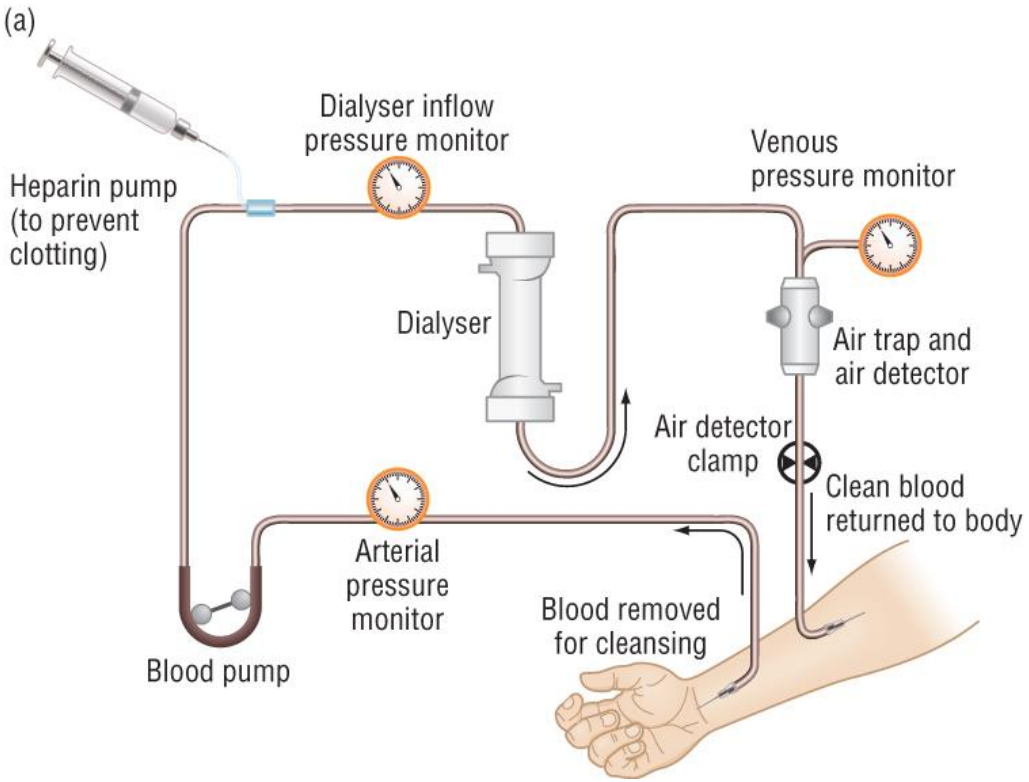
- The most common treatment.
- Blood is passed over a partially permeable dialysis membrane.
- On the other side of the membrane is a dialysis fluid containing the correct concentrations of water, salts, urea and other substances found in plasma.
- Any substance in excess in the blood diffuses out while any substance too low in concentration diffuse into the blood.

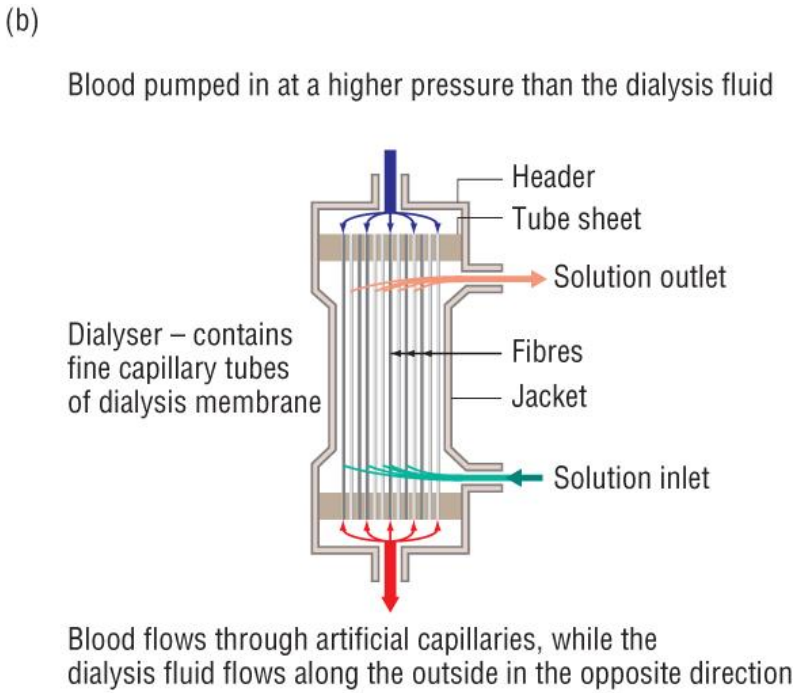
Two types of dialysis

- Haemodialysis:
- Peritoneal dialysis:

Haemodialysis:

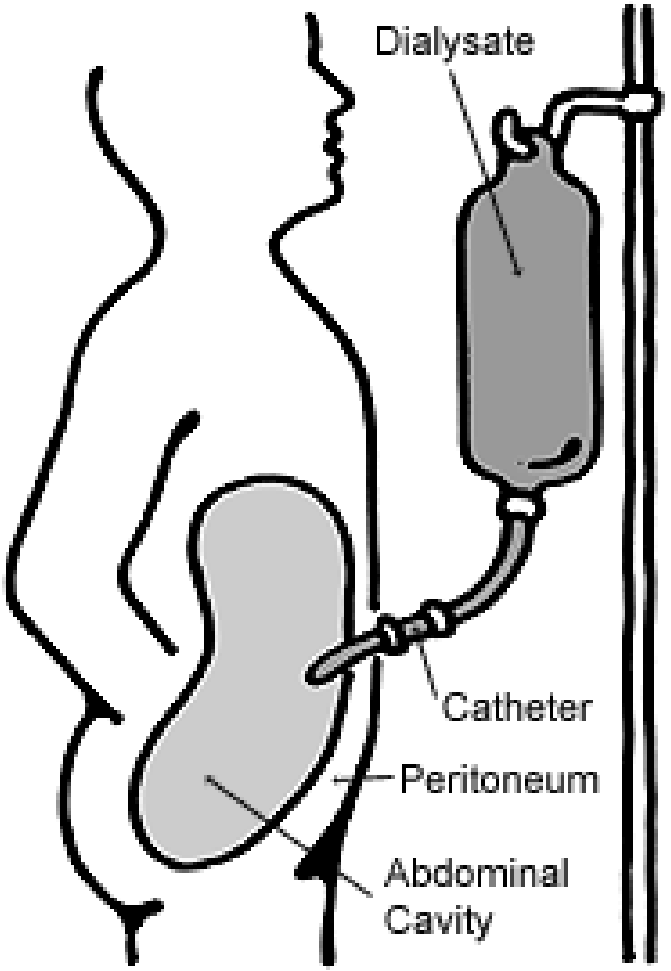
- Venous blood is pumped through a machine containing an artificial dialysis membrane.
- Dialysis occurs about 3 times a week for a few hours per session in hospital.





Peritoneal dialysis

- The body's own peritoneum acts as the dialysis membrane as dialysis fluid is pumped into the abdominal cavity.
- After a few hours this can be drained and replaced by fresh fluid. Can be done at home/work/night.



Kidney Transplant

- The best treatment we have to offer so far.