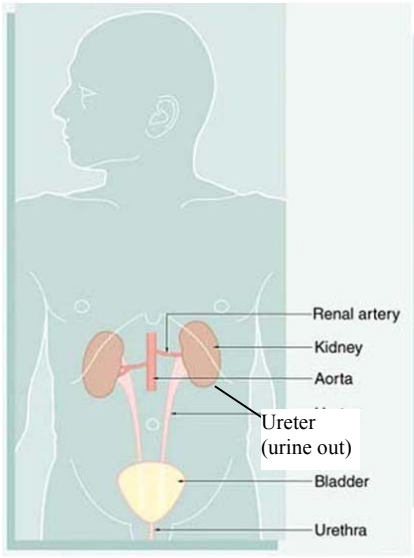
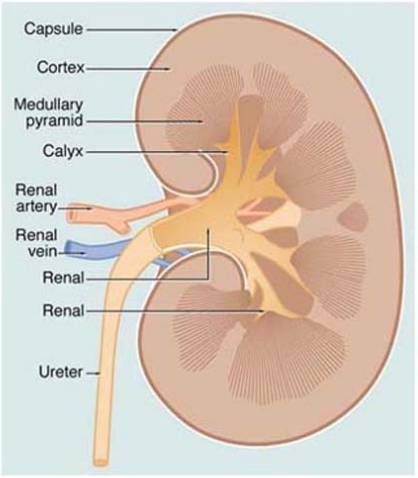
The Kidney

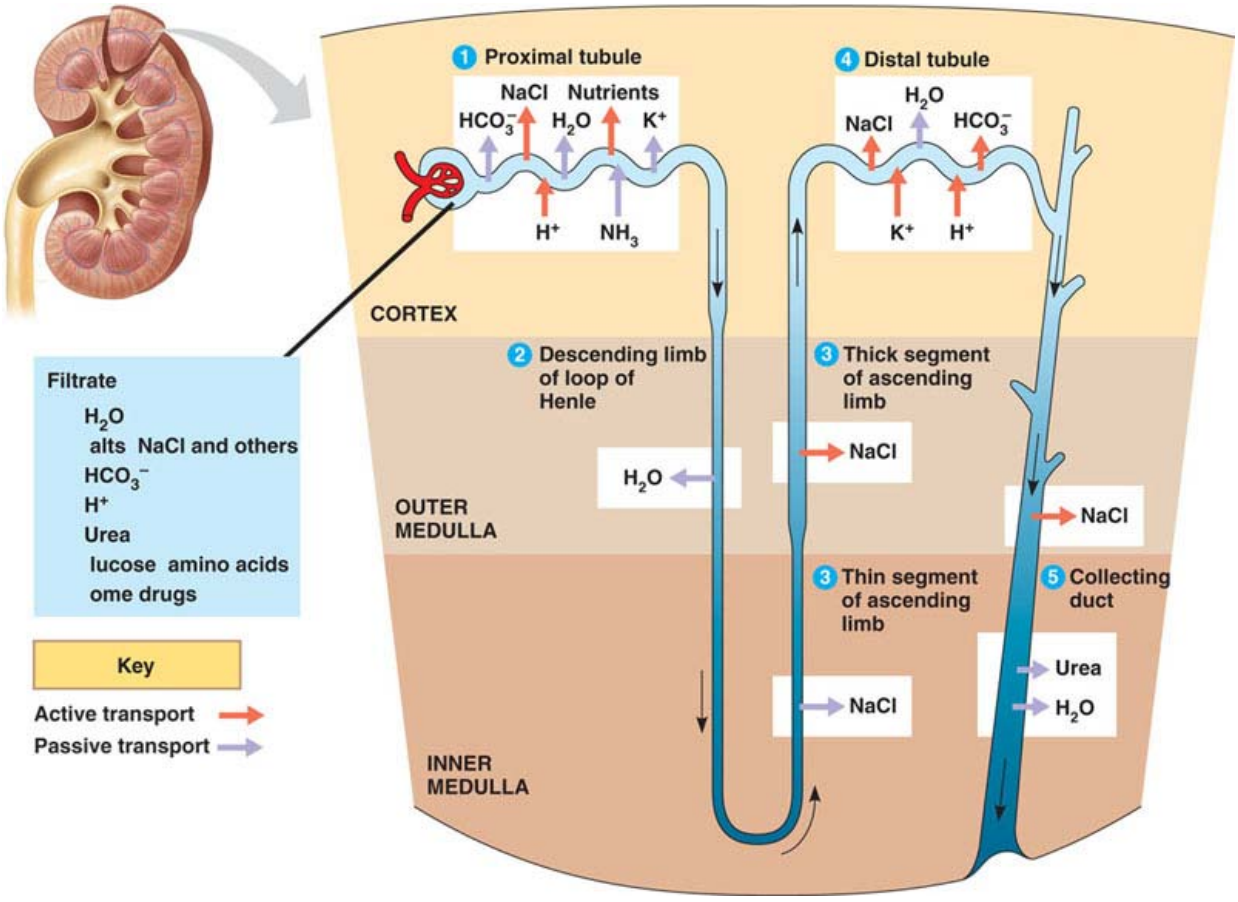
The kidneys remove urea and other toxic wastes from the blood, forming a dilute solution called **urine** in the process. The two kidneys have a very extensive blood supply and the whole blood supply passes through the kidneys every 5 minutes, ensuring that waste materials do not build up. The **renal artery** carries blood **to** the kidney, while the **renal vein** carries blood, now with far lower concentrations of urea and mineral ions, **away** from the kidney. The urine formed passes down the **ureter** to the **bladder**.



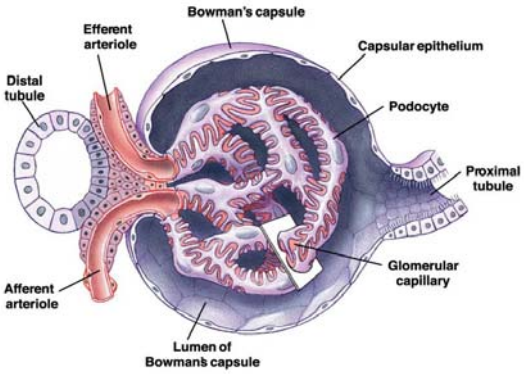


The important part of the kidney is a folded tube called a **nephron**. There are about a million nephrons in each kidney. There are five steps in producing urine in a **nephron**:

1.

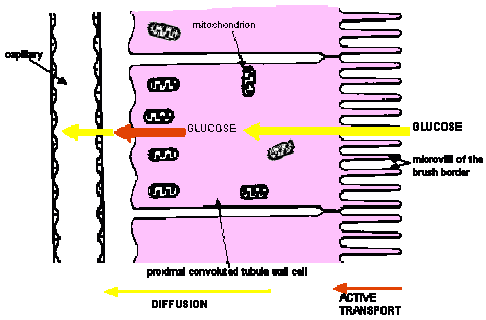


Renal capsule – Ultrafiltration



The renal artery splits into numerous **arterioles**, each feeding a **nephron**. The arteriole splits into numerous capillaries, which form a knot called a **glomerulus**. The glomerulus is enclosed by the **renal capsule** (or Bowman's capsule)- the first part of the nephron. **The arteriole leading into the glomerulus is wider than the one leading out,** so there is **high blood pressure in the capillaries of the glomerulus**. This pressure forces plasma out of the blood by **ultrafiltration**. Both the capillary walls and the capsule walls are formed from a single layer of flattened cells with gaps between them, so that all molecules with a molecular mass of < 68,000 are squeezed out of the blood to form a **filtrate** in the renal capsule. Only blood cells and large proteins (e.g. antibodies and albumin) remain in the blood.

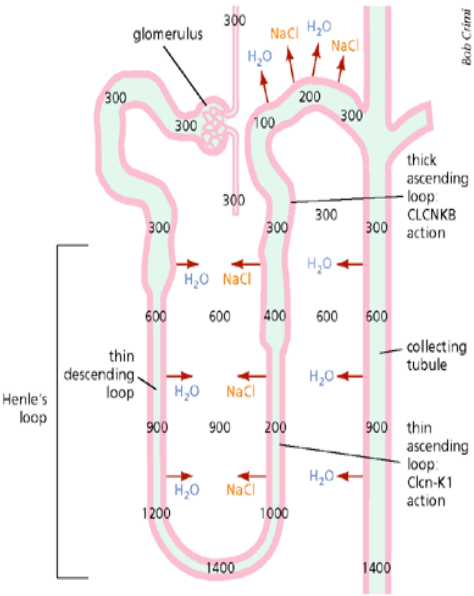
2. First (proximal) Convoluted Tubule – Reabsorption.



The **proximal convoluted tubule** is the longest (14mm) and widest (60µm) part of the nephron. It is lined with epithelial cells containing **microvilli** and numerous mitochondria. In this part of the nephron **over 80% of the filtrate is reabsorbed** into the tissue fluid and then to the blood. This ensures that all the "useful" materials that were filtered out of the blood (such as glucose and amino acids) are now returned to the blood. These cells have **microvilli**, to ensure a large surface area (Fick's Law again!)

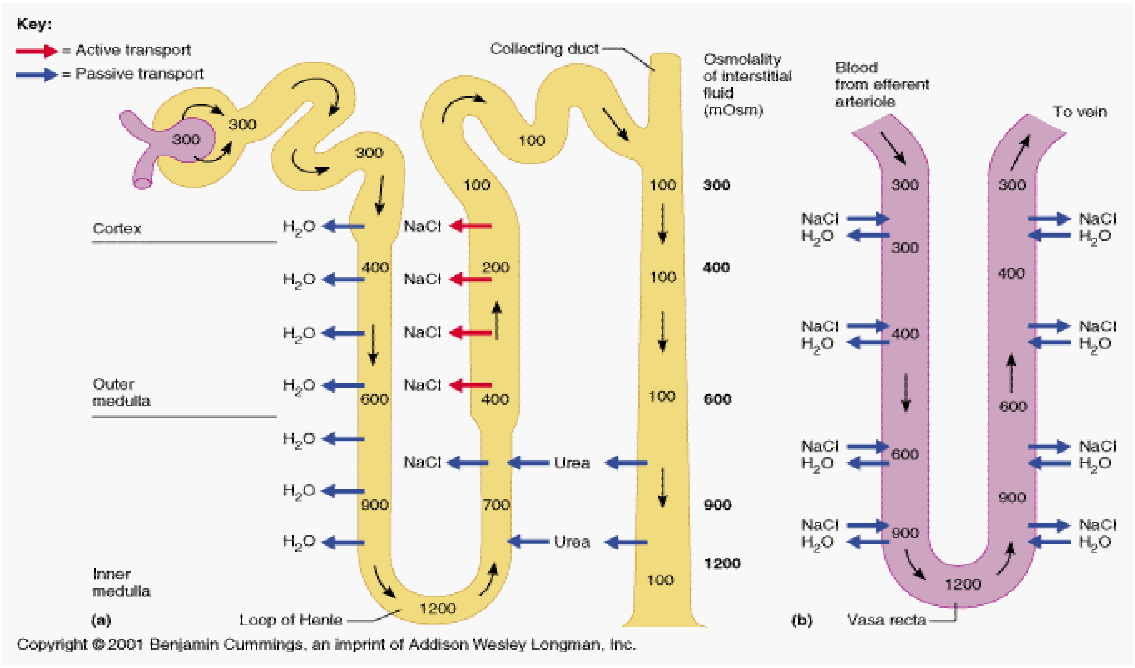
- **All glucose, all amino acids and 85% of mineral ions** are reabsorbed by **active transport** from the filtrate to the tissue fluid. They then diffuse into the blood capillaries.
- **Small proteins** are reabsorbed by **pinocytosis**, digested, and the amino acids diffuse into the blood.
- **80% of the water** is reabsorbed to the blood by **osmosis**.
- Surprisingly, **some urea is reabsorbed** to the blood by diffusion. Urea is a small, uncharged molecule, so it can pass through membranes by lipid diffusion and there isn't much the kidney can do about it. Since this is a passive process, urea diffuses down its concentration gradient until the concentrations of urea in the filtrate and blood are equal. So in each pass through the kidneys half the urea is removed from the blood and half remains in the blood.

3. Loop of Henlé – Formation of a Salt Bath.



The job of the **loop of Henlé** is to make the tissue fluid in the medulla hypertonic (i.e. **lower ψ)** compared to the filtrate in the nephron. The purpose of this "salt bath" is to reabsorb water as explained in step 5. The loop of Henlé does this by **pumping sodium and chloride ions out of the filtrate into the tissue fluid.**

The first part of the loop (the **descending limb**) is impermeable to ions, but some water leaves by **osmosis**. This makes the filtrate more concentrated as it descends. The second part of the loop (the **ascending limb**) contains a Na^+ and a Cl^- pump, so **these ions are actively transported out of the filtrate into the surrounding tissue fluid**. Water would follow by osmosis, but it can't, because **the ascending limb is impermeable to water**. So the water potential of the tissue fluid becomes lower (more salty - **lower ψ**) and the water potential of the filtrate becomes higher (less salty – **higher ψ**). Since the filtrate is **most concentrated at the base of the loop**, the tissue fluid is also more concentrated at the base of the medulla, where it is three times more concentrated than seawater.

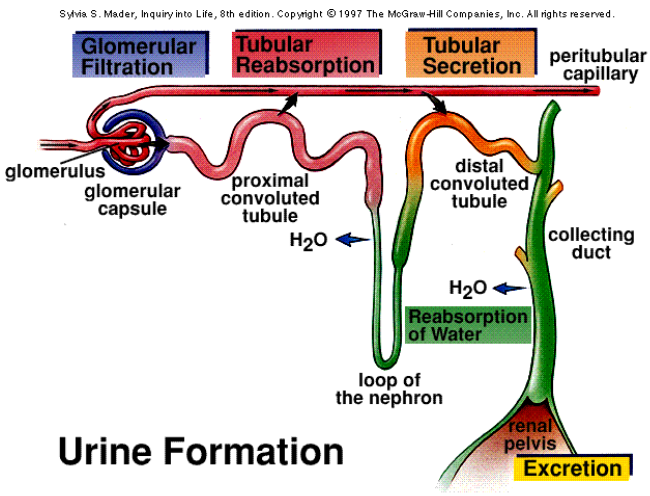


4. Distal Convoluted tubule – Homeostasis and Secretion

In the distal convoluted tubule certain substances are actively transported from the blood into the filtrate, in other words they are **secreted**. It is relatively short and **has microvilli** with numerous membrane pumps for active transport. The important point about this secretion is that it is regulated by hormones, so this is the **homeostatic** part of the kidney. Substances secreted include H^+ (for pH homeostasis), K^+ (for salt homeostasis), ethanol, toxins, drugs and other "foreign" substances.

5. Collecting Duct – Concentration

As the collecting duct passes through the hypertonic salt bath in the medulla, water leaves the filtrate by osmosis, so concentrating the urine and conserving water. The water leaves through special water channels in the cell membrane called **aquaporins**. **These aquaporin channels can be controlled by the hormone ADH (= Anti Diuretic Hormone)** , so allowing the amount of water in the urine to be controlled. **More ADH opens the channels**, so **more water is conserved** in the body, and **more concentrated urine** is produced. This is described in more detail in water homeostasis later.



The Bladder

The collecting ducts all join together in the pelvis of the kidney to form the **ureter**, which leads to the **bladder**. The filtrate, **only** now called **urine**, is produced continually by each kidney and drips into the bladder for storage. The bladder is an expandable bag, and when it is full, stretch receptors in the elastic walls send impulses to the medulla, which causes the sphincter muscles to relax, causing **urination**. This is an involuntary reflex response that we can learn to control to a certain extent when we are young.