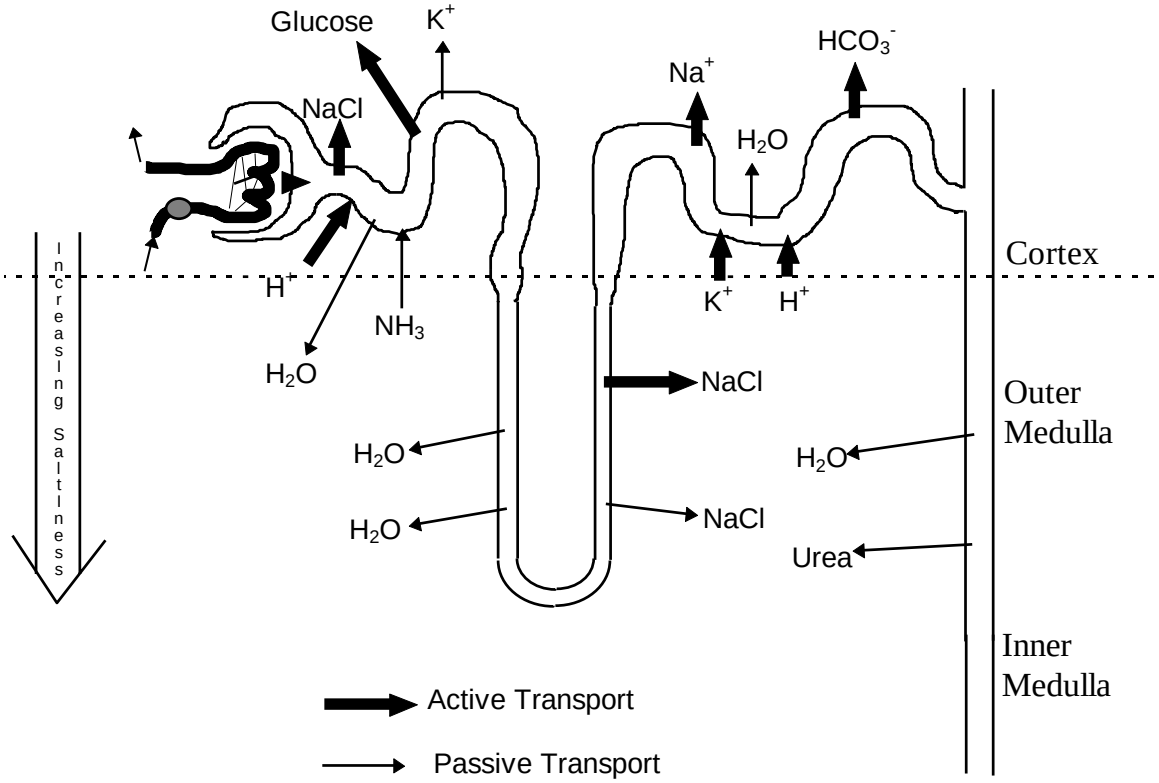
Urine Formation

Urine formation has three stages:

1. **pressure filtration**: occurs inside Bowman's capsule as molecules are forced through the glomerulus
2. **selective reabsorption**: occurs in the proximal convoluted tubule (Na^+, Cl^-, H_2O)
3. **Tubular excretion**: occurs in the distal convoluted tubule



Pressure Filtration

- Blood entering the kidneys is under **pressure**. Blood enters the Bowman's capsule and circulates through a loop of **capillaries** (glomerulus).
- Pressure **forces** small molecules (water, salts, glucose, wastes, amino acids) into Bowman's capsule
- Large molecules (proteins, blood cells) are left in the blood and circulate out the **peritubular capillary** via the efferent arteriole.
- The small, filterable molecules that are forced into Bowman's capsule form **filtrate**
- **Renin** is released in the afferent arteriole (from the juxtaglomerular apparatus) to increase blood **pressure**, if necessary.

Thinking question: What do you think would happen if the kidneys ONLY did pressure filtration?

If the kidneys only did pressure filtration, we would quickly die from water and nutrient loss – therefore the kidneys need some sort of process that reabsorbs molecules that the body needs

Selective reabsorption

- The filtrate leaves Bowman's capsule and enters the **PCT**
- The molecules that the body needs are **reabsorbed** from the PCT to the peritubular capillary network (i.e. from the tubes back to the blood)
- This initial reabsorption increases the **concentration** of the urine in the tubule.

What gets reabsorbed?

- Most of the water, nutrients, some salts (Na^+ and Cl^-); glucose and amino acids
    - Na^+ is **actively** reabsorbed (requires ATP and a carrier molecule)
    - Cl^- is **passively** reabsorbed (does not require energy to move)
    - Water is passively transported into the **blood** due to the osmotic imbalance (higher salt concentration in the blood compared to the nephron)
    - Other small molecules in high concentration include glucose and amino acids; these are valuable resources so they are **actively** reabsorbed by the blood via carrier proteins in the cell in the PCT (carrier proteins make it a selective process)

What doesn't get reabsorbed?

- Some water, wastes, excess salts
    - Non-reabsorbed material **continues** through the loop of Henle

The kidney must balance water concentration: Loop of Henle – primary role is reabsorption of water in the **descending** loop; the ascending loop **pumps** Na^+ ions out of the tubule and into the peritubular space

> Na^+ actively removed → Cl^- ions move by attraction → salty environment surrounding loop of Henle → water is drawn out of the tubule as a result → water enters peritubular capillary network → concentrated urine is left!

NaCl is **passively** transported out of the narrow portion of the ascending limb, but **actively** transported out of the thicker part of the ascending limb.

- ➔ Less salt is available as the fluid moves **up** the limb
- ➔ Water cannot leave the ascending limb because it is **impermeable**
- ➔ Inner medulla has **higher** solute concentration than upper medulla – collecting duct leaks urea

Of the 100 mL of filtrate, only **~1 mL** find its way into urine

Tubular excretion

- Occurs as molecules are too **large** to be filters into the glomerulus are **actively** transported across the wall of the DCT and into the urine
- Molecules left over from muscle metabolism, hormone breakdown, and drugs such as antibiotics are **removed** from the blood in this way
- H^+ ions, NH_3, K^+, penicillin and histamine are some chemicals that are actively excreted

Fluid now enters the **collecting** duct – urine contains substances that have undergone pressure filtration but have not been **reabsorbed** and substances that have undergone tubular excretion

The urine passes from collecting duct into the renal pelvis, enters the ureter and heads to the urinary bladder...

The Product of Nephron Function: Urine

Urine is mostly water. The actual concentration is determined by the relative concentration of water – the colour of urine can be attributed to the amount of water you consume and the amount you lose due to evaporation.

***Note: Vitamin B (riboflavin – has a bright yellow pigment) makes your pee really yellow even if you're super hydrated!*

Recall: What other substances (other than water) does urine contain and how are these wastes formed?

Dissolves salts, such as NaCl, metabolic wastes, including nitrogenous wastes (urea and ammonia) – as a result of protein breakdown that releases nitrogen compound (i.e. ammonia). Ammonia is toxic, so is quickly converted to urea in the liver (remember?!); small molecules resulting from the breakdown of hormones; occasionally there will be protein or blood in the urine – this is not normal and is usually a signal that something is not working properly (ex. High blood pressure may force proteins across glomerular walls)

Thinking question: How does urine testing for athletes work? (i.e. what is being looked for during a urine test) *Hint: small molecules result from the breakdown of* ***hormones***.

If irregular quantities of the products resulting from hormone breakdown are found in the urine, this may indicate the athlete has been taking supplements of these hormones, which are banned by most athletic regulatory bodies

Vocabulary terms to know!

- Afferent arteriole
- Bowman's capsule
- Collecting duct
- Distal convoluted tubule
- Efferent arteriole
- Pressure filtration
- glomerulus
- loop of Henle
- nephron
- peritubular capillary network
- proximal convoluted tubule
- selective reabsorption
- tubular excretion
- water reabsorption

On the diagram you drew last class:

- indicate the direction of flow of fluids, beginning with glomerular filtration into bowman's capsule and ending with urine leaving the collecting duct
- indict with arrows where each of the processes of urine formation occurs – label the arrows