You kidneys are the primary organs of excretion. Excretion is the removal of wastes from the body. The wastes we are referring to here are the products of metabolism. Anything that is excreted in urine was once a metabolic substance in your body (helping you produce energy)

**A. Functions of the Urinary System:**

1. **Excretion of Metabolic Wastes**
2. **Maintenance of Water-Salt Balance**
   - NaCl can cause osmosis in the blood. The more salt there is in the blood the more water there will be, and it will increase the blood pressure
3. **Maintenance of acid-base balance**
   - pH of blood should be around 7.4. Kidneys help monitor the blood pH level by excreting H+ ions or by reabsorbing bicarbonate ions as needed. (Like your own buffering system)
4. **Secretion of Hormones**
   - Kidneys release rennin, which leads to the secretion of aldosterone from the adrenal cortex. Aldosterone promotes the reabsorption of sodium ions by the kidneys.
B. **What are waste products and where do they come from?**

1. Ammonia =
   
   \[ \text{NH}_3: \text{from deamination of amino groups.} \]
   
   Toxic to tissues, so in land mammals NH3 converted to urea in liver.

   Urea is water-soluble - excreted in Urine

   \[ \text{Urea} \rightarrow \]

2. Creatinine:
   
   is another nitrogenous waste. Creatinine comes from creatinine phosphate in muscle metabolism (a Phosphate-storage molecule)

3. Other Excreted Substances (besides Nitrogenous wastes)
   
   →Bile pigments: from breakdown of red blood cells

   →CO2: Lungs major site of excretion

   →kidneys also excrete HCO3- (bicarbonate ion)

   →Ions: Salts K+, Na+, Ca++, Mg++, Fe+
   
   these ions are not metabolic products, but needed for various biochemical processes and must be maintained at specific concentrations. Are excreted to maintain proper balances of these ions

   →Water: metabolic end product, maintains blood pressure, consumed with food
   
   Urine is composed mainly of urea (~3%), salts ~2%, H2O (95%).
Excretion Notes

C. **Organs of Excretion and their overall functions**

1. **Kidneys:** Excrete urine, regulate blood volume, pH
   Ureters conduct urine from the kidneys to the bladder.

2. **Skin:** Glands excrete perspiration (which consists of H2O, salt, and small amounts of urea
   excretion from the skin is primary for cooling

3. **Liver:** excretes bile, which contains pigments that are breakdown products of RBC metabolism. Bile is sent to small intestine.
   Urochrome from breakdown of heme
   Urochrome gives urine its yellow colour

   **HOW DO YOU TELL IF YOU ARE HYDRATED FROM YOUR URINE COLOUR?**

4. **Lungs:** excrete CO2, some H2O

5. **Intestines:** excretes some iron and Calcium salts, which are secreted into intestine, then excreted into feces

D. **URINARY SYSTEM CONSISTS OF THESE PARTS**

1. **Renal Veins:** carries blood from kidneys back to hearty

2. **Renal Arteries:** carries blood to kidneys

3. **Kidneys:** reddish-brown organs about 4 inches long, 2 inches wide, 1 inch thick, anchored against the dorsal body wall by connective tissue.

4. **Ureters:** muscular tubes, move urine from kidneys to bladder via peristalsis

5. **Bladder:** holds up to 600 ml to 1000 ml urine, can expand/contract. Has stretch receptors that indicate when it is full, notifies the brain.
6. **Urethra**: tube connecting bladder to outside. The urethra of a man is about 6 inches long (extends through penis). In the man, the urethra also transports semen (but never at the same time as urine). For women, the urethra is only ~1 inch (which is why women get more infections here -- bacteria can invade more easily).

**Urination**: Occurs when the urinary bladder fills with about 250mL of urine. When it stretches receptors send sensory nerve impulses to the spinal cord (This is the signal that you have go!) When it is time to go sphincters relax, which is caused by motor nerve impulse from the spinal cord.

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**E. The Anatomy of your Kidneys:**
You have two kidneys. One on the right side of your body and one on your left! It can be broken down into 3 parts:

a. **Renal Cortex**: Outer part
   - outer granulated layers that dips down between a radially striated inner layer

b. **Renal Medulla**:
   - Middle
   - consists of cone shaped tissues masses called renal pyramids.

c. **Renal pelvis**: Center
   - central space that is connected with the ureter.
Kidney Stones can sometimes form in pelvis.

Kidney stones consist of Calcium salts and uric acid. They can pass naturally (ouch!) or be treated with surgery, or destroyed with sound waves or laser light. Primary Cause: too much protein in diet!

F. **How the kidney works!**
The human kidney achieves a high degree of water reabsorption by using the salts and urea in the glomerular filtrate to increase osmotic concentration of the kidney tissue. This facilitates the movement of water from the filtrate out into surrounding tissue, where it is collected by blood vessels impermeable to the high urea concentration but permeable to water

- as such human urine may be as much as 4.2 times as concentrated as blood plasma, dessert animals such as the gerbil are even higher, 14 times.

- the kidney uses the hairpin loop of Henle to set up a **countercurrent flow**. The longer the loop the greater the water reabsorption. The countercurrent processes involves the passage of two solutes across the membrane of the loop: salt (NaCl) and urea.
Basically then the kidney is divided into two zones:

1. **The outer portion, cortex**, contains the upper portion of the loop including the upper ascending arm where reabsorption of salt from the filtrate by active transport occurs.

2. **The inner portion, medulla**, contains both the lower portion of the loop and the bottom of the collecting duct, which is permeable to urea.

→ the active reabsorption of salt in the cortex drives the process. Salt reabsorption from the filtrate of one arm of the loop establishes a gradient of salt concentration, with concentration higher in the medulla at the bottom of the loop. It is the high salt concentration that raises the total osmotic concentration so high that water passes by osmosis out the collecting duct.

**G. Nephrons** - are the functional units of the kidney. They filter wastes from the blood, and retain water and other needed materials. There are about 1 million nephrons per kidney. Urine formation occurs in the nephron.

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**Filtration**

Most filtration occurs in the glomerulus. Blood pressure forces water, salt, glucose, amino acids, and urea into Bowman’s capsule. Proteins and blood cells are too large to cross the membrane, they remain in the blood. The fluid that enters the renal tubules is called the filtrate.

**Reabsorption**

As the filtrate flows through the renal tubule, most of the water and nutrients are reabsorbed into the blood. The concentrated fluid that remains is called urine.

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a. **Bowman’s Capsule (Glomerular capsule)** - Cup-like end of nephron where wastes are forced out of the blood and into the nephron. The blood enters a capillary tuft called the Glomerulus. It’s a ball of blood!

b. **Afferent Arteriole** - carries blood to Glomerulus
c. Efferent Arteriole - carries blood from Glomerulus

d. From capsule, nephron narrows into Proximal Convoluted Tubule, which makes a turn to form Loop of Henle, which is surrounded by the Peritubular capillary network (Blood re-joins the renal vein to be taken back the heart). Loop leads to the Distal Convoluted Tubule, which finally enters a collecting duct. The collecting duct takes urine to the renal pelvis.

H. Urine Formation:

1. Glomerular Filtration:
Water, salts, nutrient molecules, and waste molecules move from the glomerulus capsule. These small molecules are called the glomerular filtrate.

2. Tubular Reabsorption
Nutrient and salt molecules are actively reabsorbed from the convoluted tubules into the peritubular capillary network and water flows passively.

3. Tubular Secretion
Certain molecules (H+ and penicillin) are actively secreted from the peritubular capillary network into the convoluted tubules.
A detailed look:
i. **Glomerular Filtration:**

→ Occurs when whole blood enters the afferent arteriole and the glomerulus.

→ due to glomerular blood pressure water and small molecules move from the glomerulus to the inside of the glomerular capsule.

→ high blood pressure in Glomerulus (~60mm Hg) forces SMALL molecules [*H2O, nitrogenous wastes, *nutrients, *ions (salts)] into Bowman's capsule

→ large molecules are unable to pass (i.e. blood cells, platelets, proteins). These remain in the blood and leave the glomerulus via efferent arteriole

→ the small, filterable molecules that are forced into Bowman's capsule form filtrate

→ high blood pressure is necessary for filtration This is accomplished through the functioning of the juxtaglomerular apparatus (a special region of afferent arteriole) and will, if necessary, release RENIN to increase blood pressure.

→ People with kidney disease often have high blood pressure because their juxtaglomerular apparatus is constantly releasing rennin

**Blood has two portions:**

<table>
<thead>
<tr>
<th><strong>Filtrable Blood Components</strong></th>
<th><strong>Nonfiltrable Blood Components</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Formed Elements</td>
</tr>
<tr>
<td>Nitrogenous Wasters</td>
<td>Blood Cells and Platelets</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Plasma Proteins</td>
</tr>
<tr>
<td>Salts</td>
<td></td>
</tr>
</tbody>
</table>
ii. Tubular or Selective Reabsorption

→occurs as molecules and ions are both passively and actively reabsorbed from the nephron into the blood of the peritubular capillary network.

→If the kidneys only did pressure filtration, we would quickly die from water and nutrient loss. Once the original filtrate is made, the next task is to reabsorb molecules in filtrate that are needed by the body (e.g. water, nutrients, some salts).

→the molecules that are reabsorbed move from the proximal convoluted tubule to the peritubular capillary network (i.e. back into the blood).

→This is very efficient. Every minute about 1300 mL of blood enters the kidneys and 1299 mL of blood leaves. Only about 1 mL becomes urine.

a. WHAT GETS REABSORBED?:
most H2O, nutrients, some salts (Na+, Cl-)

b. WHAT DOESN’T GET REABSORBED:
some H2O, wastes, excess salts non-reabsorbed material continues through Loop of Henle

c. Reabsorption is both ACTIVE and PASSIVE:
ACTIVE: requires ATP and carrier molecule (e.g. glucose, Na+)
PASSIVE: diffusion! Cl-, water

→Tubular fluid now enters the LOOP OF HENLE

→primary role of Loop of Henle is reabsorption of water. Over 99% of the water in original filtrate is reabsorbed by the nephron during urine formation.

→salt (Na+Cl-) is also passively and actively reabsorbed
→this concentrates the urine, allowing it to be hypertonic to plasma
iii. **Tubular Secretion**

→ the second way which substances are removed from the blood in peritubular network and added to the tubular fluid.

→ In the end urine contains:
  1. substances that have undergone glomerular filtration but have not been reabsorbed
  2. Substance that have undergone tubular secretion

**H. Kidneys do much more than filter your blood!**

1. **Hormone Regulation**

   Regulate your volume of blood *(i.e. water volume).* This is done by two hormones: ADH and ALDOSTERONE.

   a. **ADH (ANTIDIURETIC HORMONE)** *(old name = vasopressin)*

      anti-"increased urine output", anti-"pee-more" hormone released by pituitary gland

      promotes reabsorption of water from collecting duct and distal convoluted tubule

      *Here is how ADH works:*
      1. cells in hypothalamus detect low H₂O content of blood

      2. ADH released into blood, acts on distal convoluted tubule and collecting duct

      3. more H₂O reabsorbed, volume of urine decreases

      4. therefore, blood volume increases

      5. as blood becomes more dilute, this is detected by the hypothalamus, ADH secretion stops (a negative feedback loop!)

→ **DIURETIC DRUGS,** prescribed for high blood pressure, inhibits ADH secretion - lower blood volume and thus b.p. *(cause increased urination).*

→ **ALCOHOL** also inhibits ADH secretion

   drinking alcohol therefore causes increased urination ---> dehydration ---> HANGOVER

   beer and alcohol cannot quench your thirst! *(you will urinate more liquid than you take in)*
→ inability to produce ADH causes DIABETES INSIPIDUS (= watery urine)
  • suffers urinate too much
  • thus, they lose too much salts from urine and blood ion levels drop
  • treatment is injections of ADH

b. ALDOSTERONE

this is a hormone released by ADRENAL CORTEX (adrenal glands sit on top of kidneys). Aldosterone acts on kidney to retain Na+ and excrete K+

→ concentration of sodium in blood, in turn, regulates secretion of aldosterone (another negative feedback loop)

→ [Na+] in blood important to kidneys ability to reabsorb H2O

→ if [Na+] in blood too low, too little H2O is reabsorbed, results in HYPOTENSION.

→ if [Na+] in blood too high, results in HYPERTENSION

2. Blood pH: Kidneys help maintain blood pH

→ nephrons vary the amount of H+ and NH3 that they excrete and the amount of HCO3- and Na+ they reabsorb.
  - keeps pH within normal limits.

→ if blood acidic, more H+ and ammonia excreted, and more sodium bicarbonate is reabsorbed.

  Sodium bicarbonate neutralizes acid.

  \[ \text{Na}^+\text{HCO}_3^- + \text{HOH} \rightarrow \text{H}_2\text{CO}_3 + \text{NaOH} \] (strong base)

→ if blood alkaline
  - less H+ excreted, less Na+ and HCO3- reabsorbed

→ Reabsorption and excretion of ions (e.g. K+, Mg++) by kidneys also maintains proper electrolyte balance of blood.