Homeostasis

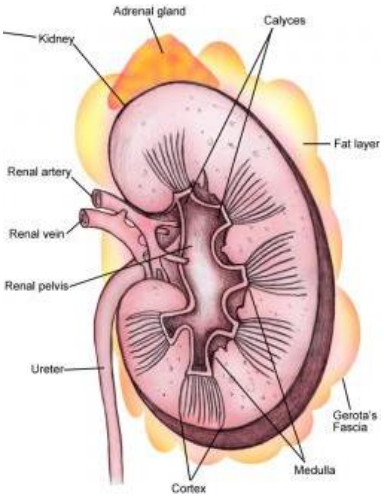
# The Excretory System

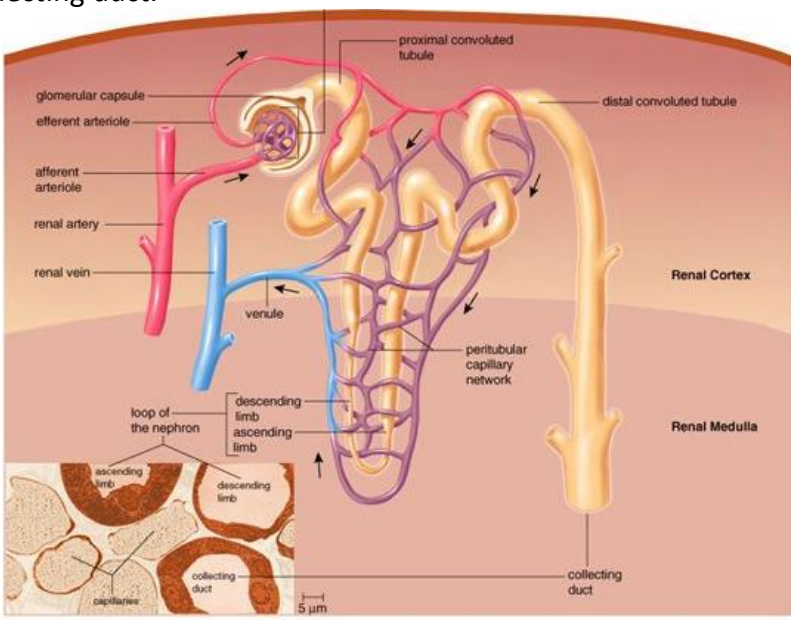
## Anatomy of the Excretory System

Consists of the kidneys, ureters, bladder and urethra. Functional unit of the kidney is the nephron and there are about one million nephrons in each kidney. These empty into the renal pelvis which narrows and forms the ureter. Urine goes through ureter to bladder and then to the urethra for exit.

### Kidney Structure

- Cortex: Kidney's outermost layer and medulla sits inside the cortex.
- Hilum: Deep slits in the center of the kidneys medial surface
    - Renal Pelvis: widest part of ureter and spans the entire width of the hilum
    - Renal artery, renal vein, and ureter enter/exit through the hilum
- Portal System: blood must travel through two capillary beds before returning to the heart
    - Afferent Arterioles: branching out of renal artery through the medulla and into the cortex
    - Glomeruli: convoluted afferent arteriole tufts
    - Efferent Arterioles: form a second capillary bed for blood after it passes through glomerulus.
        - Vasa Recta: capillaries surround the loop of Henle.
- Bowman's Capsule: cuplike structure around glomerulus. Branches out into the proximal convoluted tube, descending and ascending limbs of the loop of Henle, distal convoluted tube, and collecting duct.




### Bladder Structure

- Detrusor Muscle: muscular lining of bladder. Parasympathetic activity causes this muscle to contract.

- Internal Urethral Sphincter: consists of smooth muscle and is contracted in its normal state and is under involuntary control
- External Urethral Sphincter: skeletal muscle and under voluntary control.

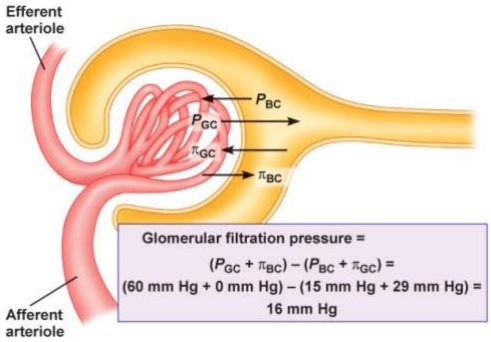
### *Micturition Reflex*

- Stretch receptors in the bladder activate which cause parasympathetic innervation to tell the detrusor muscles to contract and subsequently the internal sphincter relaxes.
- The person can then voluntarily choose to relax the external sphincter or keep it contracted.
- Urination itself is caused by the contraction of the abdominals which create pressure and compresses the bladder

## Osmoregulation

### Filtration

- First function of the nephron, 20% of blood that passes through the glomerulus is filtered as fluid into Bowman's space.
    - Collected fluid is **filtrate** and this movement is governed by **Starling's forces**
    - **Hydrostatic pressure of bluid** is stronger than the **oncotic pressure** within the nephron.
- Filtrate: similar composition to blood, but does not contain cells or proteins due to larger size molecules not being able to pass the filter.
    - Blood left in the glomerulus travels to the efferent arterioles and empties into the vasa recta.




### Secretion

- Nephrons able to secrete salts, acids, bases and urea by active and passive transport.
- Occurs outside of the Bowman's capsule and is mainly used to control the balance of larger molecules that cannot pass through the glomerulus, and for excretion of larger waste products such as urea.

### Reabsorption

- Compounds taken back up after they have been filtered or secreted.
- Glucose, amino acids, and vitamins are basically always reabsorbed.
- Hormones can alter how much water is being reabsorbed.

## Nephron Function

### Proximal Convoluted Tube

- Filtrate first enters this and Amino Acids, glucose, water-soluble vitamins and the majority of salts are reabsorbed along with water.
- 70% of filter sodium reabsorbed here.
- Solutes enter the **interstitium**, the connective tissue surrounding the nephron, and are then picked up by the vasa recta and returned to the bloodstream.
- Also a site for the secretion of wastes such as hydrogen ions, potassium ions, ammonia and urea.

### Loop of Henle

- Filtrate then enters the descending limb of the loop, which dives into medulla and then curves into the ascending limb.
- Descending limb is permeable only to water. This allows the control of water since the concentration gradient for water can be changed by altering the osmolarity of the interstitium.
- Countercurrent Multiplier System: flow of filtrate is opposite to the flow of blood in the vasa recta.
    - Since they flow in opposite directions, equilibrium is never reached since the filtrate is always being exposed to hypertonic blood.
- The ascending limb is only permeable to salts and not to water.
    - Increasing amounts of salts are removed as the ascending limb moves out of the medulla (salt concentration is higher in the medulla than in the cortex).
    - **Diluting Segment**: area of ascending limb where it becomes thicker. These cell lining contain larger amounts of mitochondria which is used to facilitate the reabsorption of sodium and chloride through active transport.
        - Only segment that can produce urine which is more dilute than blood
- At the beginning of the loop, the filtrate is isotonic to the interstitium. But at the end, it is hypotonic, which means that the urine becomes slightly diluted.
- Volume of the filtrate is significantly reduced. Accounts for the large reabs of $H_2O$.

### Distal Convoluted Tube

- Responds to aldosterone (promotes Na+ reabsorption). As sodium ions move out, water follows. Reduces volume and concentrates the urine
- Also a site of waste secretion

### Collecting Duct

- Responsive to both aldosterone and ADH/vasopressin
- Final concentration of urine depends mainly on these. If permeability increases, more water is reabsorbed.
- Almost always reabsorbs water, but amount is variable.
- End of the nephron, anything left in it will be excreted through the renal pelvis. Then to the ureter and then to the bladder.

# Functions of the Excretory System

## Blood Pressure

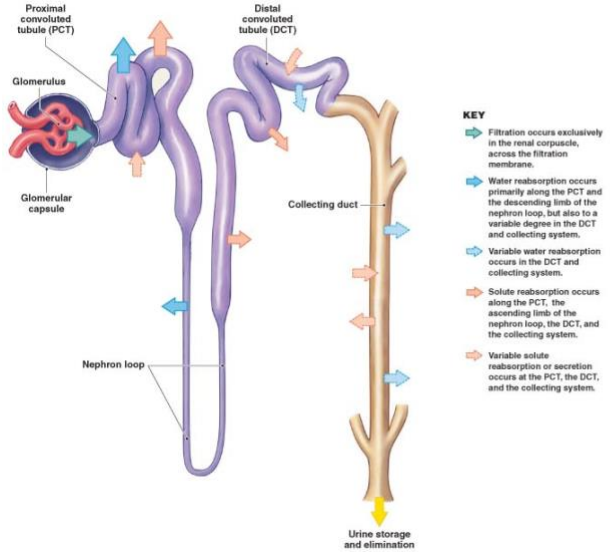
- **Aldosterone** is a steroid hormone secreted by the adrenal cortex and functions to increase the blood pressure.
    - **Renin** released from **juxtaglomerular cells** when blood pressure decreases.
    - **Angiotensinogen** cleaved by renin to form **angiotensin I**
    - **Angiotensin-converting enzyme** metabolizes angiotensin I into **angiotensin II**
    - **Angiotensin II** promotes release of aldosterone.
    - Increases collecting tube and distal convoluted tubes ability to reabsorb sodium. Water then follows and result in a net volume increase.
- **Antidiuretic Hormone**: peptide hormone made in hypothalamus and release by posterior pituitary.
- Alters the permeability of the collecting duct and allows for more water to be reabsorbed by making cell junctions “leaky.”
- Also regulated by constriction and dilation of arterioles. Lower blood pressure would mean a constriction of the afferent arterioles. This would stimulate the release of renin.

## Osmoregulation

- Osmotic pressure is the sucking pressure that draws water in and oncotic pressure is the osmotic pressure that is attributed directly to dissolved proteins.
- Kidneys control the bloods osmolarity by controlling the reabsorption of water and by filtrating or secreting dissolved particles
    - If osmolarity is low: excess water is secreted and solute absorbed in higher conc
    - If osmolarity is high: water reabsorption increases and solute excretion increases

## Acid-Base Balance

- Bicarbonate buffer system is the major regulator of blood pH.
- Excretory system can selectively control the secretion of hydrogen and bicarbonate.
    - If pH too low, kidneys excrete more hydrogen ions and increase H2CO3 reabs
    - If pH too high, opposite effect occurs.
- Slower than the respiratory system response, but is more long lasting and effective.




**Renal Structures and Their Functions**

| Segment | General Functions | Specific Functions |
|---|---|---|
| **Renal corpuscle** | *Filtration* of plasma; generates approximately 180 L/day of filtrate similar in composition to blood plasma but without plasma proteins | *Filtration:* water and inorganic and organic solutes from plasma<br>*Retention:* plasma proteins and blood cells |
| **Proximal convoluted tubule (PCT)** | *Reabsorption* of 60–70% of the water (108–116 L/day), 99–100% of the organic substrates, and 60–70% of the sodium and chloride ions in the original filtrate | *Active reabsorption:* glucose, other simple sugars, amino acids, vitamins, ions (including sodium, potassium, calcium, magnesium, phosphate, and bicarbonate)<br>*Passive reabsorption:* urea, chloride ions, lipid-soluble materials, water<br>*Secretion:* hydrogen ions, ammonium ions, creatinine, drugs, and toxins |
| **Nephron loop** | *Reabsorption* of 25% of the water (45 L/day) and 20–25% of the sodium and chloride ions present in the original filtrate; creation of the concentration gradient in the renal medulla | *Reabsorption:* sodium and chloride ions, water |
| **Distal convoluted tubule (DCT)** | *Reabsorption* of a variable amount of water (usually 5%, or 9 L/day) under ADH stimulation, and a variable amount of sodium ions under aldosterone stimulation | *Reabsorption:* sodium and chloride ions, sodium ions (variable), calcium ions (variable), water (variable)<br>*Secretion:* hydrogen ions, ammonium ions, creatinine, drugs, and toxins |
| **Collecting system** | *Reabsorption* of a variable amount of water (usually 9.3%, or 16.8 L/day) under ADH stimulation, and a variable amount of sodium ions under aldosterone stimulation | *Reabsorption:* sodium ions (variable), bicarbonate ions (variable), water (variable)<br>*Secretion:* potassium and hydrogen ions (variable) |
| **Peritubular capillaries** | *Redistribution* of water and solutes reabsorbed in the renal cortex | Return of water and solutes from the peritubular fluid to the general circulation |
| **Vasa recta** | *Redistribution* of water and solutes reabsorbed in the renal medulla, and stabilization of the concentration gradient of the renal medulla | Return of water and solutes from the peritubular fluid to the general circulation |

# Skin

## Epidermis

- Subdivided into layers called **strata**
- Stratum basale: contains stem cells that are responsible for the proliferation of **keratinocytes** (the cells which produce **keratin**).
- Stratum spinsum: cells become connected to each other and also contains Langerhans cells.
- Stratum granulosum: Keratinocytes die and lose their nuclei
- Stratum lucidum: present in thick, hairless skin (palms and soles)
- Stratum Corneum: layers of flattened keratinocytes, which form a barrier that prevents the invasion of pathogens. Also helps prevent the loss of fluids and salts.

### *Types of Cells in Epidermis*

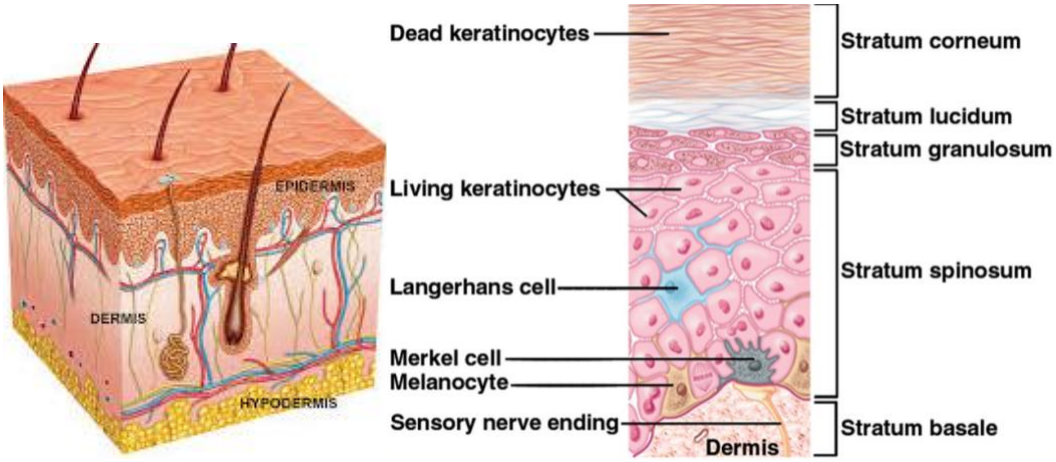
- Keratin is the main cell and is resistant to damage and provides proteion.
    - **Callusus** form from excessive keratin deposition in order to protect repeated strain areas.
    - Also produces fingernails and hair
- Melanocytes: Found in the stratum basale and produce **melanin**. Which is a pigment that protects the DNA from UV radiation.
- Langerhans Cells: special macrophages that are capable of presenting antigens to T-cells in order to activate the immune system.

## The Dermis

- Papillary Layer: the upper layer that consists of loose connective tissue.
- Reticular Layer: lays below the papillary layer and is denser
- Location of most sensory receptors and is the origin of sweat glands, blood vessels and hair follicles of the skin
- Merkel Cells: sensory neuron that is responsible for deep pressure and texture sensation
- Meissner's Corpuscles: respond to Light touch. Ruffini Endings: respond to stretch. Pacinian corpuscles: deep pressure and vibration

## Hypodermis

- Layer of connective tissue that connects the skin to the rest of the body.
- Contains fat and fibrous tissue



## Thermoregulation

- Achieved by sweating, piloerection, vasodilation, and vasoconstriction
- Sweating: controlled by the autonomic nervous system
    - When temp rises: postganglionic sympathetic neurons use Ach to promote the secretion of water
    - Heat is then absorbed from the body when water is evaporated
    - Vasodilation also occurs in order to maximize heat loss
- In cold conditions: **arrector pili** muscles contract and this causes the hairs of the skin to stand up (**piloerection**). Causes layer of heat to be trapped.
    - Capillaries also constrict to reduce amount of blood reaching the skin
    - **Shivering** is when the skeletal muscles begin to contract rapidly and uses a lot of ATP.
- Fat helps to insulate body from cold weather. This is **white fat**.
- **Brown fat** can also be present, and is much less efficient at transporting electrons, so more energy is released as fuel is burned. This is present in infants.