CLASS – 11

BIOLOGY

Chapter – 19: ExcretoryProducts and Their Elimination

HUMAN KIDNEY

- Located on either side of backbone, close to dorsal inner wall of abdominal cavity.
- 10cm long, 5-7 cm wide, 2-3 cm thickness.
- Hilum (median indention) present toward cortex on concave side of kidney.
- Left kidney position higher than right one in human.
- In **rabbit** right kidney is higher position, In **cat** both kidney in same level

INTERNAL STRUCTURE OF KIDNEY

- In V.S of kidney following region can be seen-

1. **Renal Cortex:**
   - Outer most regions toward convex surface.
   - Contain gloeruli of nephrons.
2. **Renal Medulla:**
   - Present just inner to renal cortex.
   - Divide in medullary pyramids (i.e conical masses)
   - Contain- renal tubules, collecting ducts, blood vessels.
   - Urine drained into renal pelvis through minute opening at papillae of pyramids.
   - Cortex extended in between the medullary pyramids as renal column called columns of Bertini.
3. **Renal Pelvis:**
   - It is large funnel shaped behind the medulla region.

- Urine collect into renal pelvis and passed down to the ureters.

NEPHRON

- Functional unit of kidney.
- More than 1.2 million of neprons are present in kidney.
- Each is 3 cm long.
- Originates in cortex region and extended into medulla region.
- Each nephron consists of five anatomical regions.

1. Renal capsule or Malpighian body (Bowmen capsule and Glomerules).
2. Proximal convoluted tubule.
3. Loop of Henle (Ascending limb and descending limb).
4. Distal convoluted tubule (DTC).
5. Collecting tubule.

RENAL CORPUSCLE OR MALPIGHIAN BODY

Bowmen's capsule:

- Cup shape structure.
- Lined by *squamous epithelial layer*.
- Enclosed glomerules (i.e network of capillaries).
- Have *cavity of Bowman's capsule* (i.e cavity between epithelial layers).

Glomerulus:

- Network of capillaries.
- Blood in glomerules –

  1. Receives from *renal artery* through afferent arteriole.

  2. Leave through efferent arteriole into renal veins.

- Efferent arteriole breaks into network of capillaries which surround – PCT, Loop of Henle, DCT.
- Capillaries joint together and return the blood into *renal vein*.

PROXIMAL CONVOLUTED TUBULE (PCT)

- Lead from renal corpuscle.
- Present in cortex region.
- Lined with cuboidal ciliated epithelium with numerous microvilli (increase the surface area).
- Mitochondria present at basal surface (allow absorption of salt by active tranport).
- Function – transport glomerul filtrate from bowman's capsule into loop of henle.

LOOP OF HENLE

- U Shaped loop which continue from PCT.
- Descends down from cortex to medulla and return back in cortex after forming a loop.
- Function – Re-absorption of salt and water.

Descending limb of loop of Henle:

- Thin and long.
- Freely permeable to water.
- Lined with flattened cuboidal epithelium

Ascending limb of loop of Henle:

- Thick, lined with flattened cuboidal epithelium with microvilli and mitochondria.
- Impermeable to water and Sodium Chloride.

DISTAL CONVOLUTED TUBULE (DCT):

- Continue from ascending limb of loop of Henle.
- Located in renal cortex.
- Lined by cuboidal epithelium.
- Function – Re-absorption of water.

COLLECTION TUBULE:

- Resent in renal cortex.
- Lined by cuboidal epithelium.

- Open into large collecting duct.
- Little absorption of water.

DUCT OF BELLINI:

- Form by joining of number of collecting ducts.
- Present in medulla region.
- Open into renal pelvis.
- Drain all urine collected from various nephrons.

VASA RECTAE:

- Capillary arise from efferent arteriole and run parallel to loop of Henle and medulla.
- Help in retaining reabsorbs ions and urea by medullary interstitial fluid.
- Parallel arrangement also helps in concentration of urine in lop of Henle.

TYPE OF NEPHRONS

Cortical Nephrons:

- Have short loop of Henle.
- Loop of Henle extends to a short distance.
- Glommeruli are in outer cortex.
- More common (85%).

Juxta medullary Nephron:

- Have long loop of Henle.
- Loop of Henle place deep into medulla.
- Glomuruli placed closed to inner margin if the cortex.
- Less in number (15%).

URINE FORMATION

- It involve following steps-

1. Glomerule filtration or ultra filtration.
2. Selective reabsorption.
3. Tubular secretion.

Glomerule filtration/Ultrafiltration:

- Blood of glomerules capillaries filtered and protein free glomerular filtrate is formed in Bowmen's capsule.
- Blood from afferent arteriole passes through three barrier:

1. Endothelium of capillaries (porous).
2. Basement membrane (act as filter).
3. Epithelial lining of Bowmen's Capsule (porous).

- Glomerular filtrate has same component as blood but except without plasma protein and blood cells.
- Bowman's capsule lined with cells of *podocytes* which form a network of slits i.e filtrate slits.
- Filtrate of slits allow ultra filtration of small molecule from glomeruler filtrate which are enough to pass through filtering membrane and large particle remain in capillaries and pass out through efferent arteriole.
- GF = blood plasma without plasma protein.
- Ultrafiltration is physical process so energy derives from hydrostatic pressure of blood.
- Hydrostatic pressure in glomerular capillaries = 70mm of Hg.
- Osmotic pressure of plasma protein = 30mm Hg.
- Net Filtration pressure (NFP) =

Hydrostatic pressure in Glomerular capillaries **-** **(**OP of plasma protein **+** Glomerular filtrate pressure**)**

= 70 – (30+20)

= 70 – 50

= 20mm Hg

- Glomerular filtrate rate(GRF) = 125ml/min

= 7500ml/hr

= 180 liter/day

 # If blood pressure fall severally then ultra filtration gets reduced.

 # If blood pressure fall below the OP of plasma proteins then urine formation stop altogether.

AUTOREGULATION OF GLOMERULAR FILTRATION

Myogenic Mechanism

- It reduces the variation in the amount of blood that flow through glomerules.
- Normally afferent arteriole stretches and increases the blood flow to the glomerules.
- ***But when blood pressure increase –***

Wall of afferent arteriole respond to stretch by contraction which reduce the diameter of arteriole which increase the resistance to flow.

JUXTA GLOMERULUS APPARETUS (JGA)

- Group of cells.
- Located between DTC and afferent arterioles, closed to glomerulus.
- JG cells – secrete enzyme ***Renin*** (modulate BP, regulate blood flow) through glomerulus and GFR.
- When GFR fall –

Renin stimulate the glomerular blood flow though which GFR come back to normal

TUBULAR OR SELECTIVE REABSORPTION

- In a day, 1.2 liter of urine comes out from 180 liters of glomerular filtrate.
- By ultra filtration – much useful substance filtered out as glomerular filtrate from blood.
- All these (useful substance) are selectively reabsorbed by vasa recta.
- Selective absorption occur through –

1. Osmosis
2. Active absorption.

Selective absorption through osmosis:

- Na and chloride – reabsorbed by passive diffusion or osmosis.
- These (Na and chloride) move in and out wherever nephron is permeable (eg. PCT).
- Water, urea, ammonia and ketone bodies also reabsorbed by osmosis.
- By selective reabsorption – 80% of water and 50% urea reabsorbed into blood from glomerular filtrate.

Active Absorption:

- Help in reabsorption of glucose and amino acid into blood from filtrate because active reabsorption takes place against concentration gradients.

TUBULAR SECRETION

- Most tubular secretion occur in DCT like :

1. Ions – Potassium, Sodium , Hydrogen.
2. Certain Drugs.
3. Metabolic waste – Creatinine (i.e formed by muscle metabolism of creatine, and Ammonia from (metabolism of protein).

They are reabsorbs by tubule and secreted into its lumen which become part of Urine.

- K^+ secreted in DCT in exchange of reabsorption of Na^+.
- Uric acid and ammonia also secreted in DCT and collecting tubule.
- Tubular secretion –

1. ***Less important in mammals.***
2. ***More important in Marine Fish and Desert Amphibians because they do not have glomerule in their nephron so all nitrogen waste (urea, creatinine ad minerals ions) are directly secreted into tubules.***

FUNCTION OF TUBULES

Role of PCT:

- 80% of glomeruler filtrate reabsorbs in PCT.
- Filtrate in PCT is isotonic to blood plasma.

Role of Loop of Henle:

- Involve in concentration of urine.
- Also increase NaCl concentration in medullar region to extract water from collecting tubule which makes urine hypertonic (i.e more concentrated than blood).
- Maintain high osmolarity of medullary interstitial fluid.
- Descending limb – permeable to water but impermeable to electrolytes (Na^+ and Cl^-).
- Ascending limb – impermeable to water but allow transport of electrolytes (Na^+ and Cl^-) active or passive mean.

Role of DCT:

- In this Na^+ and H_2O reabsorb against concentration gradient.
- In exchange of Na^+, K^+ excreted in urine.
- Na^+ actively transported.
- Chloride ions move out passively from the filtrate and reabsorbed.
- Reabsorption of H_2O regulated by ADH (i.e release from posterior pituitary).
- It maintains pH, salt and water balance of blood.
- Also capable to –

1. Reabsorb HCo_3 ions.
2. Selective secretion of H^+, K^+, and NH3 to maintain pH and sodium, potassium balance in blood.

Role of Collection duct:

- Cuboidal epithelium of collecting duct is permeable to water but not to NaCl.
- Also take filtrate toward renal medulla for the second time to become more and more concentrated (i.e filtrate) as water is lost to interstitial fluid.
- Later part of collecting duct is permeable to urea.

 # Leakage of urea in interstitial fluid responsible for high osmotic concentration of renal medullary intestritium at collecting duct region.

- Play important role in maintenance of pH and ionic balance of blood by selective secretion of H^+ and K^+.

MECHANISM OF CONCENTRATION OF FILTRATE

COUNTER CURRENT SYSTEM IN LOOP OF HENLE:

- Hair pin counter current system is form due to fluid flow in opposite direction in both limb of loop of Henle.

1. Descending limb:

- Permeable to water but not to salt (NaCl).
- As descending limb move down into the renal medulla – osmotic loss of water from filtrate occur – help to concentrate NaCl in the filtrate.
- Filter enter from PCT to descending limb is isotonic to blood
- But when it flow down to descending limb it become hypertonic because 5% water flow out by osmosis (i.e reabsorb by vasa rectae).

 # Filtrate becomes more and more concentrated as it moves towards the apex of the loop.

2. Ascending limb:

- Impermeable to water and permeable to NaCl (i.e only thin segment not thick one).
- As filtrate move up in ascending limb-

NaCl is actively removed from it to interstitial tissue of medulla and diffuse passively into descending limb.

- Filtrate in ascending limb become less concentrated or hypertonic as it move u due to impermeability of water (i.e water doe not move out along with salt).
- High salt concentration in medullary tissue occurs due to continuous movement of Na^+ and chloride ions from ascending limb.
- High salt concentration in medulla results – outward movement of water (by osmosis) from

collecting ducts which lead production of hypertonic or concentrated urine.

- Counter current system of vasa rectae
- Vasa rectae is blood capillaries in the form of loop flowing very close and parallel to booth limbs of loop of Henle.
- Due to narrow structure of vasa rectae only 1% of total renal blood flow (very slow and sluggish) through them.
- Counter current arrangement form when blood is entering in descending capillary come closer to blood flowing out from ascending capillary.
- Counter current arrangement – lead high salt and urea concentration in the medulla region due to opposite directional flow of blood in two limb of vasa rectae.

 # In mammal's concentration of urine directly related to length of loop of Henle.

Example:

1. *Beaver lives in aquatic habitat – short loop of Henle – Produce dilute (hypotonic) urine.*
2. *Kangaroo, Rat lives in desert – long loop of Henle – produce concentrated (hypotonic) urine.*

DIFFERENCES BETWEEN DESCENDING LIMB AND ASCENDING LIMB OF LOOP OF HENLE

Descending Limb:

- Freely permeable to water and NaCl.
- 5% of water drawn out of the filtrate by vasa rectae (reabsorbed).
- Nephric filtrate becomes hypertonic due to loss of water.
- It is first part of loop of henle that gets isotonic filtrate from PCT.

Ascending Limb:

- Impermeable to water and NaCl.
- Water is not reabsorbed.
- Active transport of sodium and chloride ion out of the filtrate.
- Nephric filtrate becomes hypotonic due to loss of solute.
- It is second part of loop of henle and passes hypotonic filtrate to DCT.

DIFFERENCE BETWEEN PCT AND DCT

Proximal Convoluted Tubule (PCT)

- It transports glomerular filtrate from Bowmen's capsule to descending limb of loop of Henle.
- 80% of glomerular filtrate is reabsorbed which include glucose, amino acid, 70% of NaCl and 80%of water.
- Not under the control of ADH.
- **Distal Convoluted Tubule (DCT)**
- Transport renal filtrate from ascending limb of loop of Henle to collecting tubule.
- It regulate the amount of salt, water and pH of blood by selective reabsorption and tubular secreation.
- ADH controls the reabsorption of water and salt.

REGULATION OF KIDNEY BY FEEDBACK CIRCUITS

1. Control by ADH Hormone:

- Permeability of DCT and collecting duct affect by ADH or Vasopressin (i.e release by posterior pituitary.
- Large amount of water in urine known as Diuresis.
- Action of ADH is to absorb water and make urine **hypertonic**.
- Regulation of water by ADH is example of homeostatic feedback mechanism.
- Due to reduced or excessive intake of water –

Osmoreceptor (i.e present in hypothalamus) detect the variation in osmotic pressure in blood and operate feedback mechanism as given below in diagram: (present in PPT)

2. <u>Control by Juxta glomerular apparatus (JGA):</u>

- Juxta glomerular apparatus situated next to the Bowman's capsule.
- JGA detect the low blood volume and falls of blood pressure (due to loss of Na ions and water in body by osmosis).
- JGA operate ***Renin-Angiotensin-Aldosteron System*** to regulate salt balance in body.

Decease in blood volume or blood pressure (due to decrease in blood Na ions level).

Reduced blood flow in afferent arteriole of glomerulus.

Low blood flow in afferent arteriole detected by JGA.

JGA release enzyme Renin into bloodstream.

Angiostensinogen convert by Renin into Angiotensis II

 # Angiotensin II –

1. Increase blood pressure by causing constriction of arterioles.

2. Increase blood volume by two way:

a) By signaling PCT to reabsorb more NaCl and water.

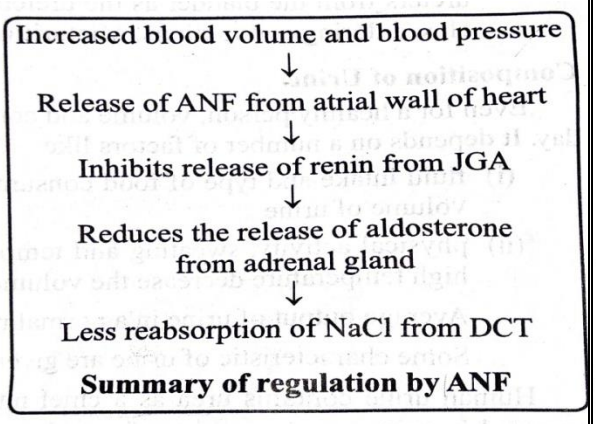
b) By stimulating Adrenal gland to release aldosterone.

Now Angiotensin II stimulates adrenal cortex (i.e Adrenal gland) to release hormone Aldosteron.

Aldosteron act o DCT and stimulate reabsorption of Na^+ and water.

Results increase in blood volume and blood pressure.

3. <u>Role of Atrial Natriuretio Factor to increased blood volume</u>



Summary of regulation by ANF

COMPOSITION OF URINE

- **<u>Factor affecting Composition of urine:</u>**

1. Fluid intake and type of food consume.
2. Physical activity, sweating and temperature.

- **<u>Composition of urine:</u>**

1. Nitrogenous waste (Urea , Ammonia, Uric Acid)
2. Creatinine
3. Hippuric acid
4. Salt (NaCl)
5. Trace of mineral ions – (Sulphates, chlorides, Phosphates, Calcium, and Magnesium).
6. Non nitrogenous substance (Vitamin-C, Oxalic Acid, Alcohol and Phenolic Substance).

- **<u>Characteristic of Urine:</u>**

1. Pale yellow color (due to pigment Urochrome).
2. Hypertonic .
3. **pH – 6** (slightly acidic).

DISORDER OF EXCRETORY SYSTEM

1. **Glycosuria:** Condition when glucose appeared in urine (diabetes mellitus).
2. **Uremia:** Abnormal rise of blood urea level due to kidney failure.
3. **Proteinuria:** Presence of excess protein in urine.
4. **Albuminuria:** Presence of albumin in urine due to renal disorder.
5. **Ketonuria :** Presence of high amount of keton bodies in urine.
6. **Haematuria:** Presence of blood cell in urine.

7. **Hemoglobinuria:** Presence of hemoglobin in urine.
8. **Diabetes Insipidus:** Production of hypertonic urine due to failure of releasing sufficient amount of ADH required.

- Control by large fluid intake to compensate loss of water in urine.

9. **Glomerulonephritis:** Inflammation of glomeruli of kidney.

1. **Proliferative:** increase in number of cells in glomerulus.
2. **Non-proliferative:** absence of increase in number of cells in glomeruli.

10. **Renal Calculi:** Stone or insoluble mass or crystallized salts formed with in kidney.

HAEMODIALYSIS

- **Uremia** (i.e increased urea concentration in blood) cause due to malfunctioning of kidney.
- In such case - patient's urea removes by haemodialysis.
- **Cause of kidney failure are-**

1. Bacterial infection.
2. Effect of toxins.
3. Inadequate blood flow to kidney or injury to kidney.

Aftificial Kindney: Device use to clean blood from metabolic waste and maintain osmoregulation of body.

- Work on the principal of dialysis.
- In artificial kidney blood flow through long semi permeable membrane tubes :

It is impermeable to large molecule *(plasma protein)* and permeable *(urea, metabolic waste and mineral ions)*.

- Dialysis tank contain dialysate or dialysing fluid (*contain small molecule and mineral ions but not contain waste products*).

Dialysis: Separation of small molecule from large one by using semi-permeable membrane.

BLOOD DIALYSIS OR HAEMODIALYSIS:

- Separate small molecule (urea and metabolic waste) from blood while large one (protein) retain in blood plasma.

Process of heamodialysis

Patient blood taken out from artery

Cooled at 0^{o} C and then mixed Anticoagulant (heparin).

Then pumped into artificial kidney to remove the metabolic waste.

During dialysis waste product diffuse out from blood into the dialysis because blood and dialysate flow in opposite direction.

Blood cleared from waste product but does not loose its plasma proteins.

Clear blood come out from apparatus and warmed up to body temperature.

Now anti-heparin mixed into blood to restore coagulability.

Return to veins of patients.