Handwritten Notes

on

Excretory Products and their Elimination

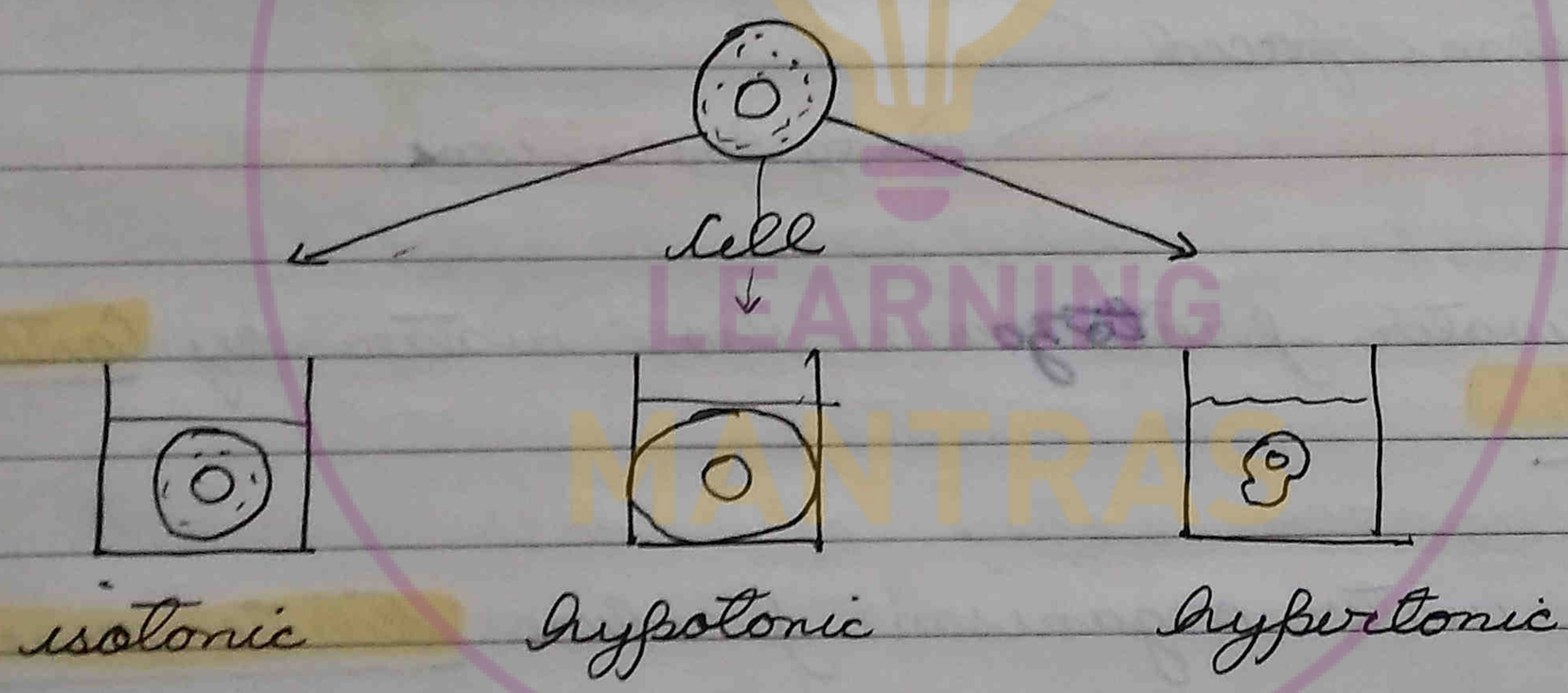
LearningMantrasOfficial LearningMantras

Excretory Products and their Elimination

- Excretion → Removal of nitrogenous wastes produced during metabolism of proteins and nucleic acids.

- Osmoregulation → Maintenance of osmolarity of the extra-cellular fluid.

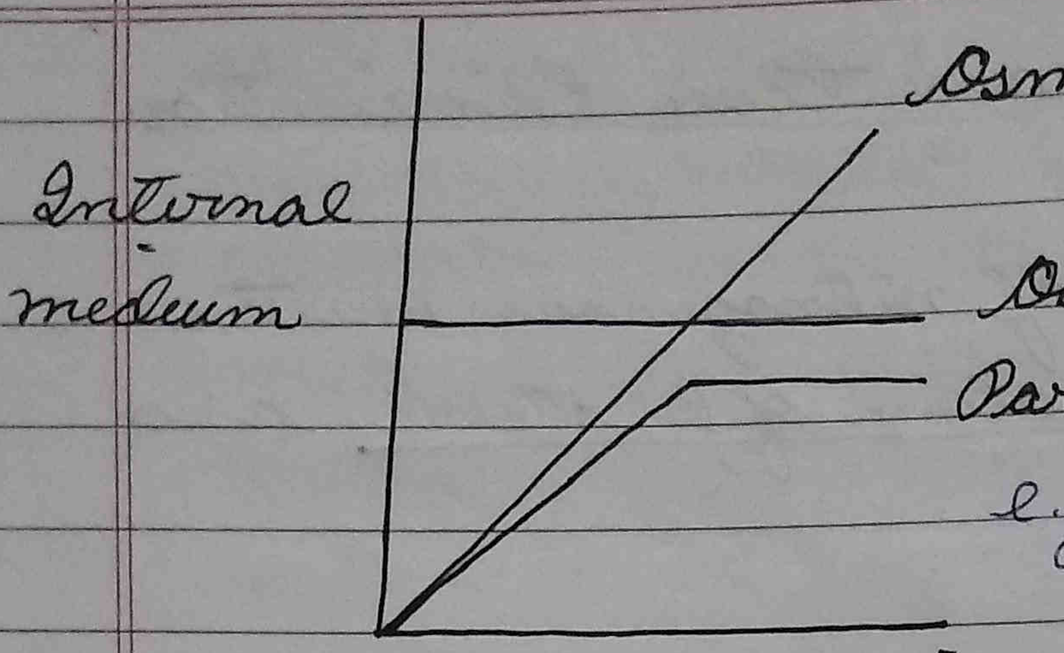
- Osmolarity → Amount of solutes dissolved per litre of solution.
  Unit - milli Osmol / litre or m Osm/L



Osmoregulation

- Osmoconformers → Animals that change their body osmolarity according to external medium.
  e.g Invertebrates, Myxine (Hag-fish) vertebrate

- Osmoregulators → Animals that maintain a constant osmolarity of body fluids irrespective of external medium.
  e.g Vertebrates except myxine.



- Osmoregulation in Fresh Water Habitat

- Hypotonic to the osmolarity of body fluids.
- Problems faced — Body gains water.
  — Body looses ions.
- Freshwater protozoans loose water by Contractile Vacuole.
- Fresh water organisms produce dilute urine.
- Bony fish (Teleosts)
  - → Do not drink water
  - Produce dilute urine.
  - Ionocytes / Chloride cells on gill membrane actively transport Na^+ and Cl^- from external medium to inside the body.

- Seabirds excrete ions with the help of nasal glands.
- Orbital glands of crocodile and turtle near eye excrete salts.

Osmoregulation in Marine Habitats

External medium

- Hypertonic to body fluids
  - Problems faced
    - Body loses water
    - Body gains ions.

- Elasmobranchs (Cartilage fish) and Latimeria (Coelocanth).
  - Retain Urea and TMAO (Trimethylamine oxide) in blood so that the osmolarity of blood is raised as a result there is no loss of water.
  - Rectal gland actively excretes ions.

- Teleosts (Bony fish)
  - ✓ Divalent ions (Mg^{2+}, SO_4^{2-}) are removed along with faeces.
  - ✓ Monovalent ions (Na^+, Cl^-) are removed actively by ionocytes.

Osmoregulation in Terrestrial Habitat

- Amniotes (Reptiles, Birds, Mammals) and Insects:
  - Insects:- have waxy epicuticle over exoskeleton which prevents water loss.
  - Excretion of uric acid which requires least amount of water.

- Amniotes: Keratinised stratum corneum (skin) which prevents water loss.

  - Kangro Rat - desert Mammal
    - Only mammal which never drinks water.
    - Nocturnal and remain in burrows during day time.
    - They have nasal counter current heat exchanger. ← exhaled air
      → Retrieve the water vapour from the air to be exhaled.
    - Produce highly concentrated urine.
    - They utilise metabolic water obtained from oxidation of food.

  - Camel - desert mammal.
    - Water is stored in the tissues and then can survive without water for many days.
    - Highly concentrated urine.
    - Store food in humps
    - Body has high tolerance for increase in temperature.

- Ammonia can be excreted by only aquatic animals as there is plenty of available water.

- Humans cannot tolerate if the water loss is 12% but camels can tolerate dehydration of twice of this value.

- Excretory Products

- Amino acids → Asterias, Unio

- Ammonia → NH_4^+ is highly toxic and highly soluble in water, thus requires large quantities of water for its excretion.
  e.g. Cnidarians, Protozoans, Sponges, flat worms, Polychaetis, Crustaceans, bony fish, tadpoles, aquatic amphibians.

- Ammonia excreting animals are called ammonotelic and this property is called ammonotelism.

- Urea →
  Urea excreting animals are called ureotelic and this property is called ureotelism.
  e.g. Adult amphibians and Mammals, cartilaginous & marine & some fishes

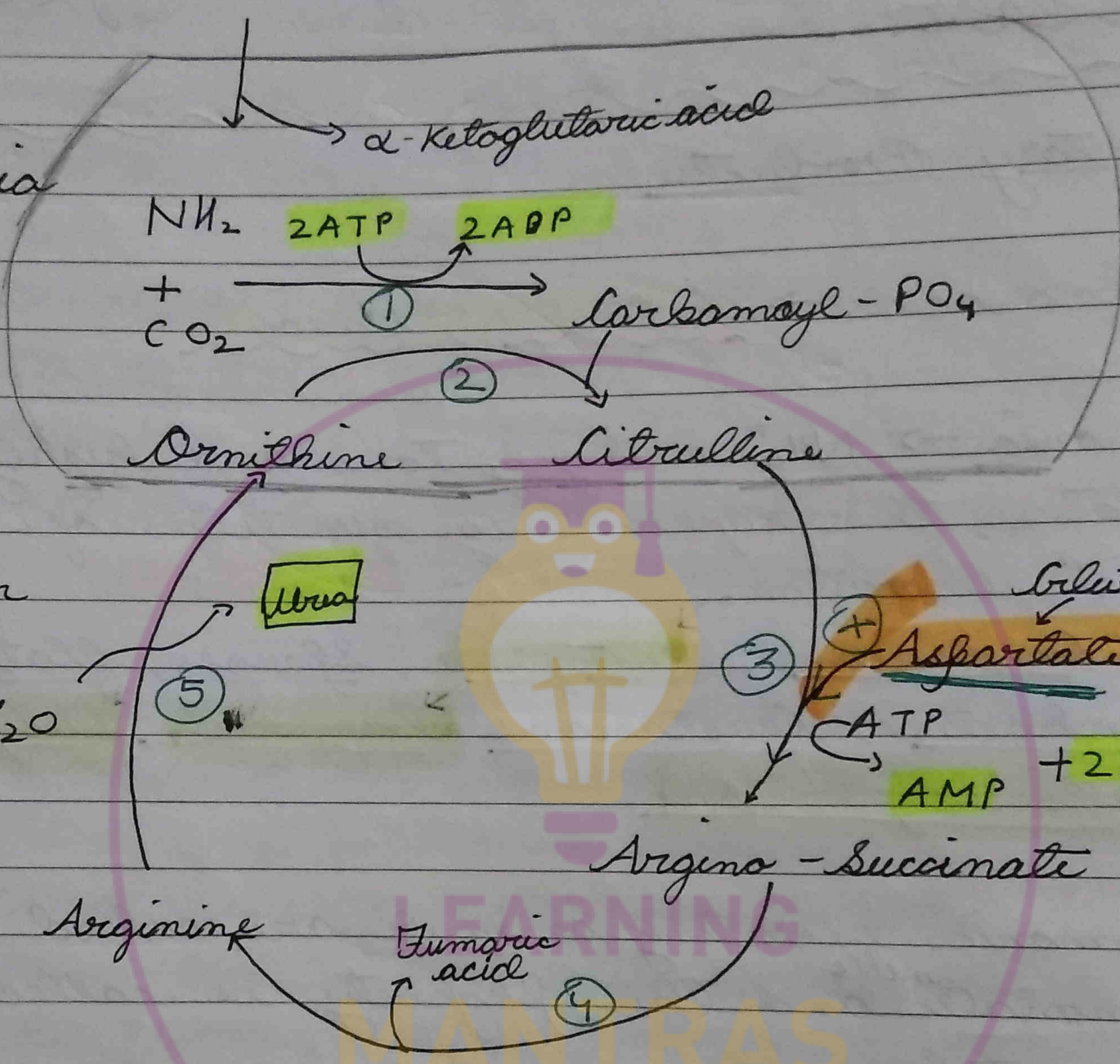
- Ammonia is converted to urea so in liver by utilising energy.

- Urea is less toxic and less soluble and hence requires lesser water for excretion.

- ~~NH_2~~ NK_2 is added in step 1 and step 3.
- Urea cycle remains both CO_2 and NH_2
- Urea is formed by hydrolysis of Arginine

Urea Cycle / Krebs Henseleit Cycle (In Liver)

☆ Urea - NH_2CONH_2



☆
1. Carbamoyl - PO_4 Synthetase
2. Ornithine Trans - carbamoylase.
3. Arginio - Succinate Synthetase
4. Argino - Succinate Lyase
5. Arginase.

- 3 ATP are used for formation of 1 - molecule of urea.
- 4 Phosphate bonds are broken for formation of 1 molecule of Urea.

☆ Urea in Urine is formed from Ammonia, CO_2 and Aspartic acid

- Uric acid is the most expensive waste as it requires high amount of energy for its formation.
- Benzoic acid is a product of fat metabolism.

☆ Spiders and Birds excrete phosphorous in form of guanine.

- Uric Acid

– Least toxic and least soluble in water.
e.g Birds, Reptiles (lizards, snakes), land snails.

– ☆ In mammals, small amount of uric acid is formed by metabolism of purines.

☆ Gouty Arthritis – due to accumulation of uric acid near the joints.

– Animals which excrete uric acid are called uricotelic and this process is called uricotelism.

- TMAO (Trimethylamine oxide)

– Ammonia is converted to TMAO.

– Soluble in water but non-toxic.
e.g some teleosts excrete it but elasmobranchs retain it.

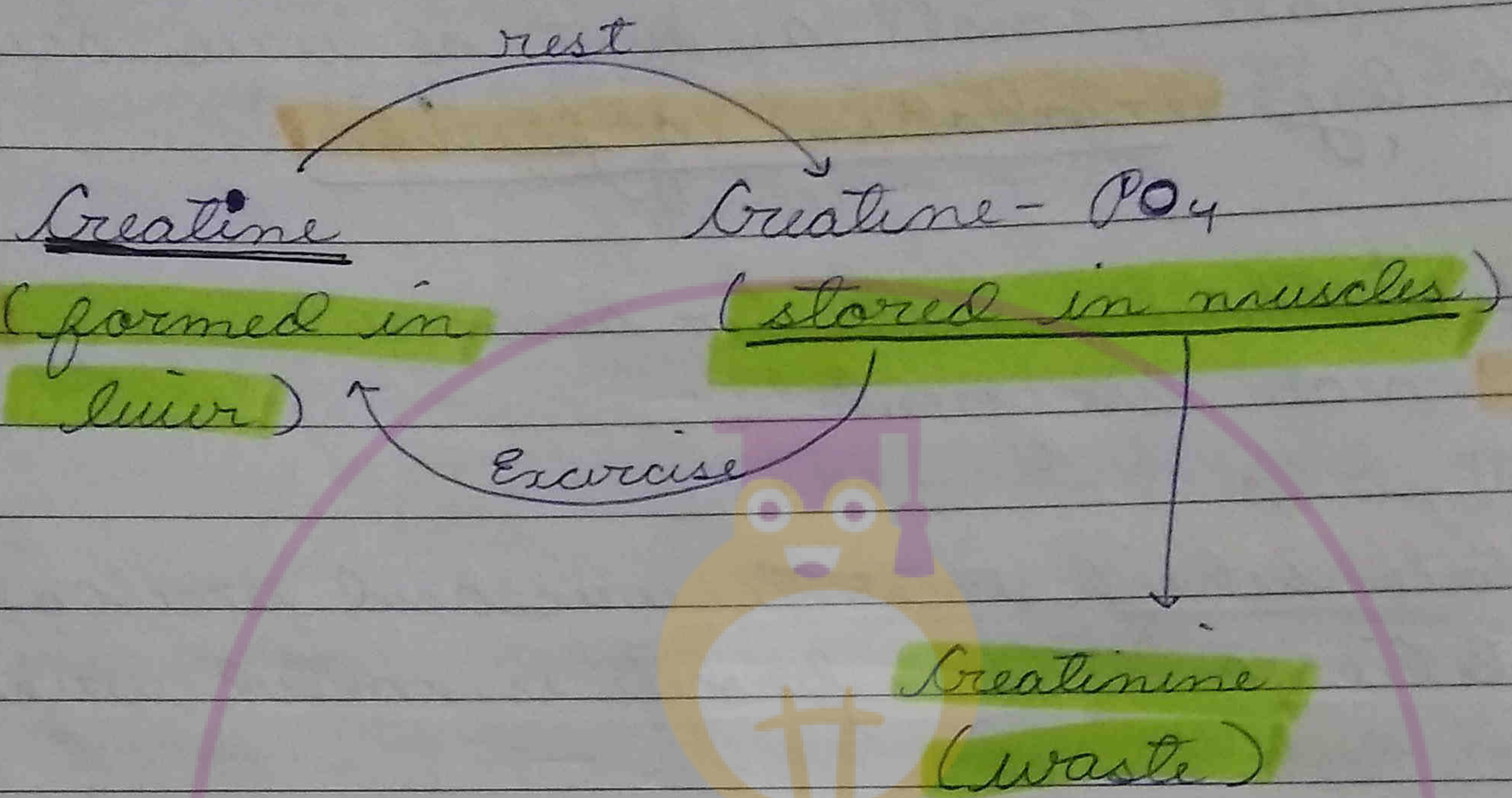
- ☆ Guanine (Purine) → contains phosphorous
– Insoluble in water and excreted in the form of crystals.
e.g in Spiders and some birds

- Hippuric acid
Mammals excrete benzoic acid as hippuric acid.

- Ornithuric acid
Birds excrete Benzoic acid as ornithuric acid

- Ornithuric acid
Birds excrete benzoic acids as ornithuric acid.

- Creatine and Creatinine



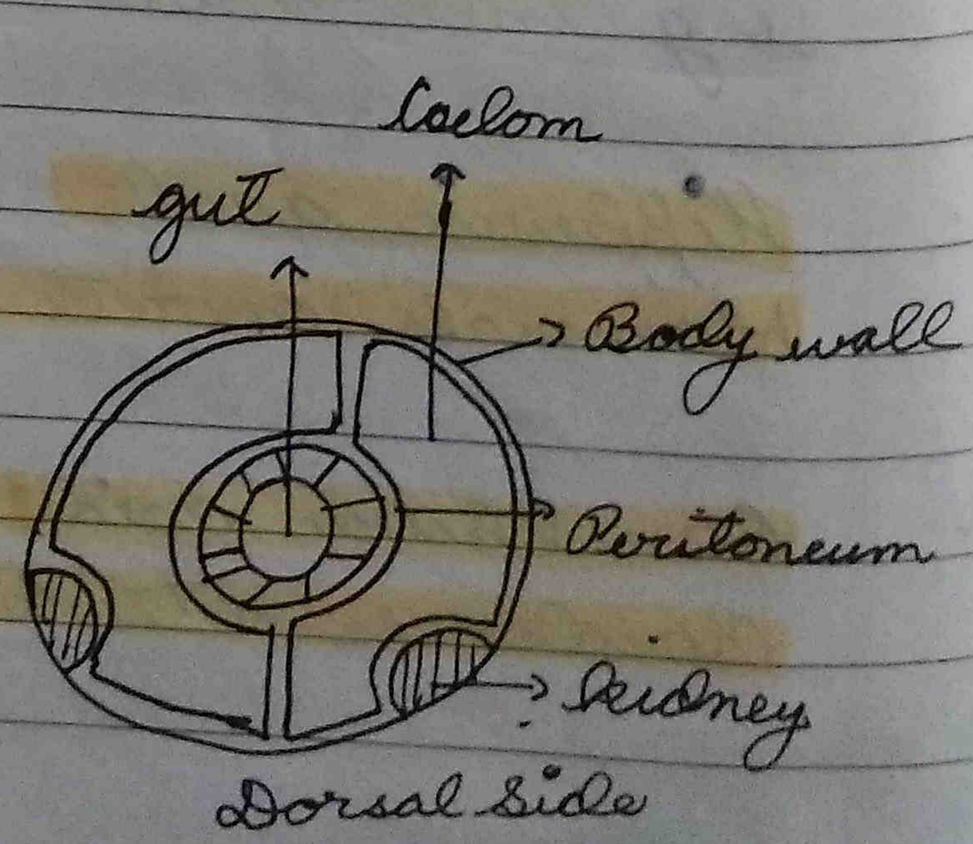
★ - Creatine — appears in urine of females, and infants and people with less muscles as it is stored in muscles.

Human Excretory System

It consists of:
Pair of Kidneys
Pair of Ureters
Urinary bladder
Urethra.

- Kidneys

Retroperitoneal - covered by peritoneum only on ventral side.



from ↑

Metanephric kidney → Functional kidney develops from posterior part of embryonic kidney

T_{12} — L_3

12th Thoracic Vertebra to 3rd Lumbar vertebra

- Right kidney is lower than left kidney, so as to accomodate the liver.

L.S of Kidney

- Pudenal nerve can control external sphincter so that a person can directly & voluntarily control micturition.
- Detrusor muscle has three layers of muscles.

- Structure of Urinary System
  - Ureter ——→ Hollow tubes.

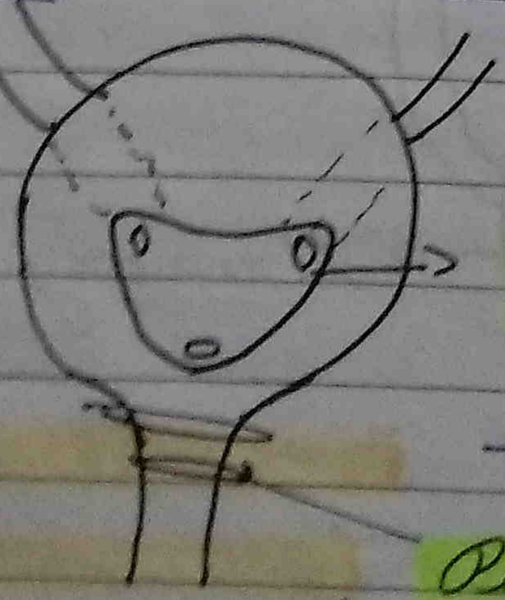
    Wall of ureter -
    - Innermost — Transitional epithelium (can stretch)
    - Middle layer — Muscular
      Longitudnal and circular muscles.
    - Outermost — Tunica adventitia (connective tissue)

    Urine moves through ureters by peristalsis.

- Urinary Bladder

  Muscular Layer → Detrusor Muscle

  It has three layers of muscles:
  Longitudnal — Circular — Longitudnal



Micturation
Voiding of urine

→ Trigone

700 - 800 ml of urine can be stored

Pudenal Nerve.
(acts on external sphincter)

- Urinary tract infections are more common in females as they have short urethra hence bacteria have to travel shorter distance to reach urinary bladder.

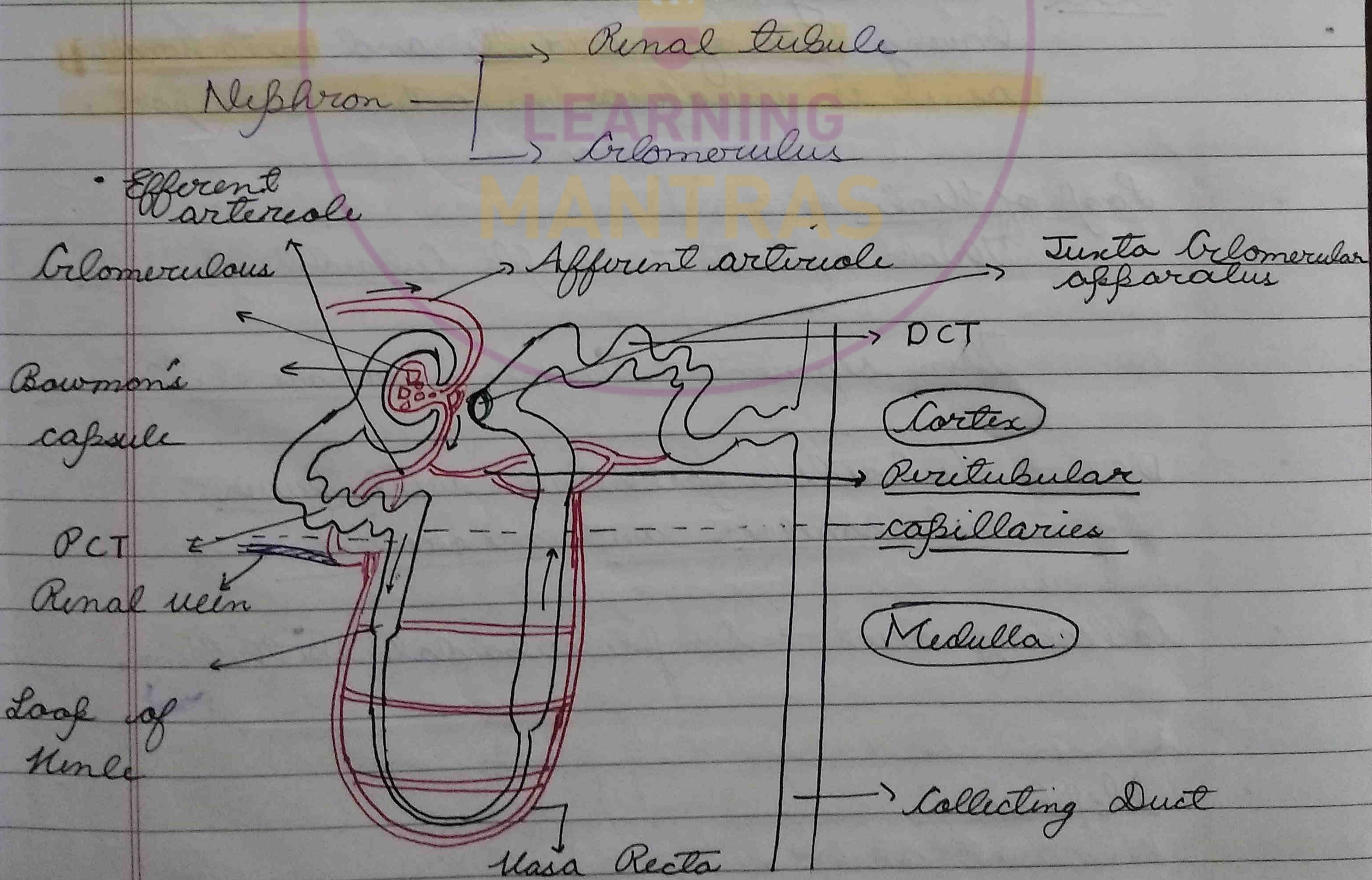
- Incontinence: inability to control micturation.

- Urethra — Conducts the urine from urinary bladder to outside.

  Females — short urethra
  Males — long urethra, common passage for semen.

Structure of Nephron

Nephron / Uriniferous tubule → it is the structural and functional unit of kidneys.



- ☆ Nephron consists of only PCT, Bowmans capsule, DCT and Loop of Henle (NBPC) Collecting duct.

- Glomerular capillary are highly permeable as compared to normal capillaries as in them squamous cells have large gaps between them.

- **Histology of Nephric Tubule**

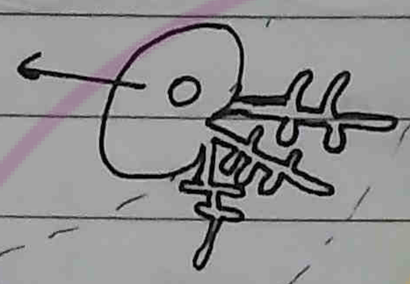
- Bowman's Capsule →

  Outer lining → simple squamous epithelium ★Q

  Inner lining → ★Q squamous cells / Podocytes

  → Glomerular capillary

  Podocytes (squamous cells with finger like projections)

  Filtration Slits of 25nm in diameter

- PCT → Lined by ★★Q brush bordered cuboidal epithelium having lots of microvilli and mitochondria as it is involved in active transport.

- **Loop of Henle**

  Thick segment - Simple cuboidal epithelium

  Thin segment - Simple Squamous epithelium

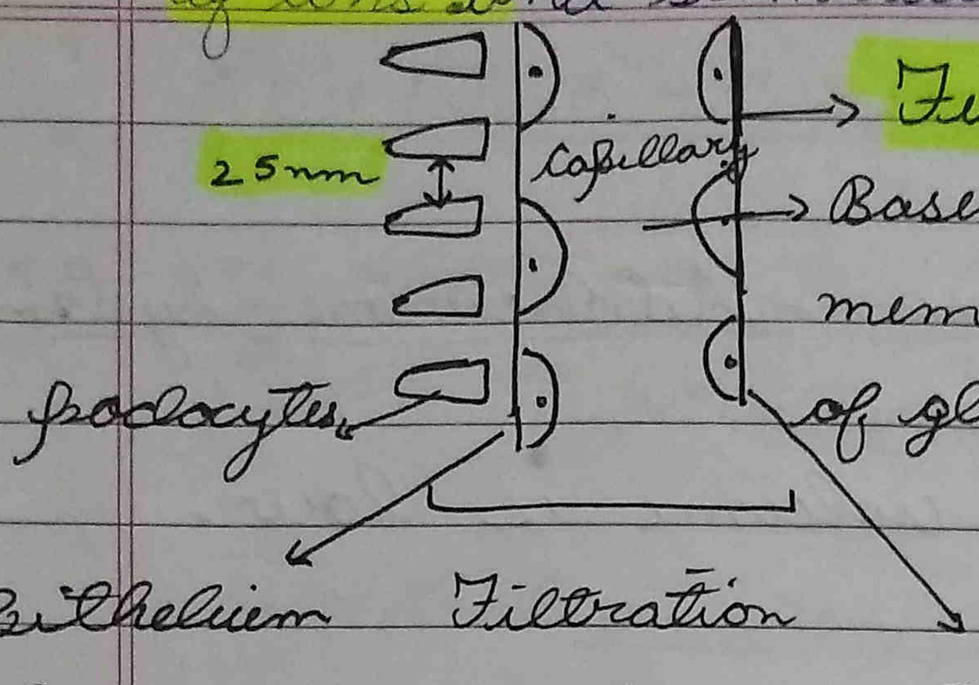
- DCT → Cuboidal epithelium with fewer mitochondria and microvilli.

- Collecting duct → Simple cuboidal epithelium.

- **Nephron**

Glomerulus → tuft of capillaries

- Podocytes + Basement membrane = filtration membrane
- ☆ Effective filtration is due to Basement membrane.
- Macula densa works as a censor to check concentration of ions and stimulates JG cells to release Renin.



→ Fenestra (70-90nm) broad: These are gaps b/w the cells

Bowman's capsule + Glomerulus = Renal Capsule / Malphigian Corpuscle

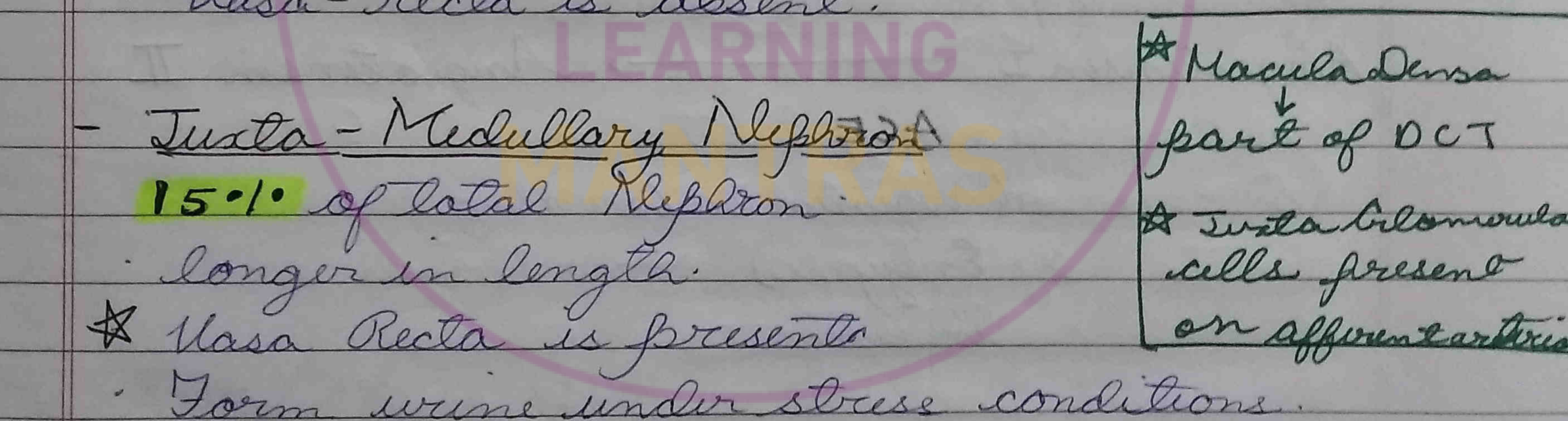
Types of Nephrons

- Cortical nephron — 85% of total nephrons.
  - shorter in length
  - Major part is in cortex.
  - Form urine in normal conditions.
  - ☆ Vasa-recta is absent.

- Juxta-Medullary Nephron
  - 15% of total Nephron.
  - longer in length.
  - ☆ Vasa Recta is present.
  - Form urine under stress conditions.

☆ Macula Densa ↓ part of DCT
☆ Juxta Glomerular cells present on afferent arteriole

Juxta-Glomerular Apparatus (JGA)



Macula Densa: tightly packed columnar cells (Part of DCT)

- Macula Densa senses low level of Na^+ and Cl^- and stimulates JG cells to release renin.

- **Osmoregulation**

RAAS (Renin - Angiotensin - Aldosterone - System)

- Activated when blood volume is low.
- Low B.P
- Low Na^+, Cl^-

JG cells release **Renin**

- Angiotensinogen — plasma protein synthesised in liver.

Angiotensinogen —(Renin)→ Angiotensin I
(Inactive precursor) (Intermediate)

Angiotensin I —(ACE (Angiotensin Converting Enzyme) in lungs.)→ Angiotensin II

- Angiotensin II stimulates adrenal cortex to release **Aldosterone** because of which Na^+ and Cl^- reabsorption increases.

- Angiotensin II causes **vasoconstruction** because of which there is **rise in Blood pressure**.

- Na^+ level and high Blood Pressure gives (-ve) feedback to Renin.

☆ RAAS, ADH and ANF together work to maintain amount of water and ions in body.

- ADH (Anti-diuretic Hormone) / Vasopressin.
- Synthesised by hypothalamus and released by posterior pituitary.
- Secreted in response to high blood osmolarity.
  300 mOsm/L (normal)
  300+ (high)
- ☆ High osmolarity is detected by ☆ osmoreceptors in Hypothalamus.
- Thirst Centre in hypothalamus is stimulated and intake of water occurs.

☆. ADH makes DCT and collecting duct permeable to water which leads to formation of concentrated urine.

- If osmolarity becomes less than 300 then further ADH secretion is stopped.

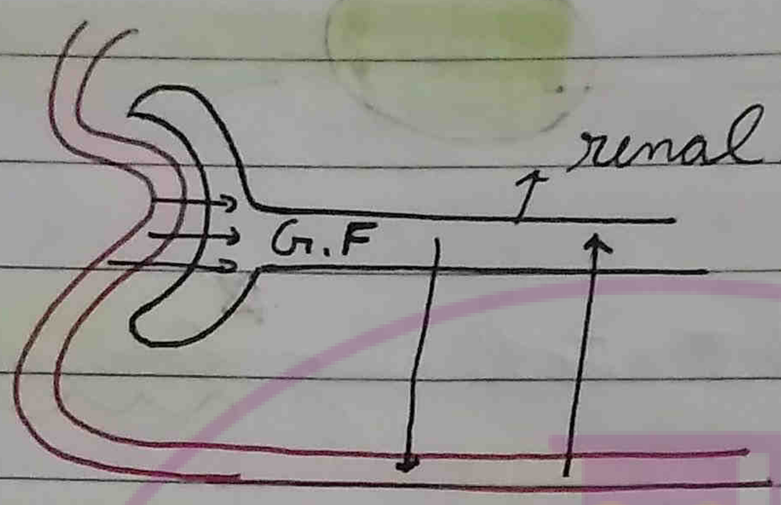
- ANF (Atrial Natriuretic Factor)
- Secreted by wall of atria (heart).
- Secreted in response to high B.P, high Na^+, high blood volume.
- Opposes RAAS and ADH.

Natriuresis (Na^+ in urine) occurs
Diuresis (watery urine) occurs

Urine Formation

Occurs in 3 steps →

(i) - Glomerular filtration
(ii) - Selective / Tubular reabsorption
(iii) - Tubular Secretion.



GF : Glomerular filtrate.

Glomerul filtration

Non - selective passive process in which blood plasma is filtered due to Glomerular Hydrostatic pressure (GHP).

Pressure favouring filtration is GHP (Glomerular Hydrostatic Pressure) which is due to broad afferent arteriole and narrow efferent arteriole

GHP = 60 mm of Hg

Pressure opposing filtration

(i) BCOP (Blood Colloidal Osmotic Pressure)
Due to albumin proteins in blood.

BCOP = 30 mm of Hg

- GFR remains nearly same as it is under autoregulation.
- NO is a vasodilator. (Nitric oxide)
- Proteins are not present in glomerular filtrate due to their large ~~cell~~ size.

(ii) CHP (Capsular Hydrostatic Pressure)

Due to fluid in Bowman's Capsule.

CHP = 20 mm of Hg

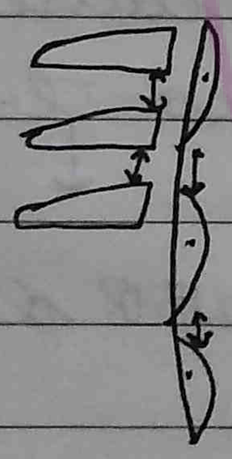
Effective/Net Filtration Pressure = GHP − (BCOP + CHP)

EFP/NFP = 60 − (30 + 20)

= 10 mm of Hg.

Glomerular Filtrate (G.F) — Same as plasma but proteins are absent.

It contains water, ions, glucose, amino acids, water soluble vitamins, Urea, Uric acid.



① Filtration slits 25nm
② Basement membrane
③ Fenestra 70-90nm

] 3 layers:

allows passage of those substances which are less than (8 nm) (Hence Basement membrane is most important in filtration)

- Glomerular Filtration Rate

125 ml/min or 180 L/day

- Autoregulation of GFR. (Glomerular filtration rate) occurs ↑. Hence amount of G.F almost remains constant.

- Because of high GFR PCT cannot reabsorb ions hence GFR has to be maintained.
- NO is potent vasodilator.
- Renal blood flow is 20-25 % of blood pumped by heart/minute

Disturbance

↓ increasing

GFR

↓

Sensors - Macula densa sense larger amount of Na^+, Cl^-, water

★

① Myogenic Regulation
Afferent arteriole constricts
↓
GFR decreases - and causes more construction

② Tubulo glomerular regulation
↓
Inhibits NO
↓
GFR decreases - and causes more construction

Sympathetic Nervous System
↓
Norepinephrine causes construction
↓
GFR decrease

- Glomerular filtrate

Renal blood flow = 1100 - 1200 ml/min

Renal plasma flow (RPF) = 600 - 700 ml/min

GFR = 125 ml/min

★ Filtrate fraction = $\frac{GFR}{RPF} = \frac{125}{600} \times 100$

= 16 - 20 %

- In diabetes melitus glucose level in blood has crossed Renal threshold.

☆ The complete blood volume is filtered about 60 times per day.

GFR = 180 L/Day

Total Blood = 5L Plasma = 3L

☆ No. of times the plasma is filtered = $\frac{180}{3}$ = 60 times.

- Urine Formation
  - Glomerular filtration
  - Tubular Reabsorption
  - Tubular Secretion.

- Tubular Reabsorption

Substances that are reabsorbed.

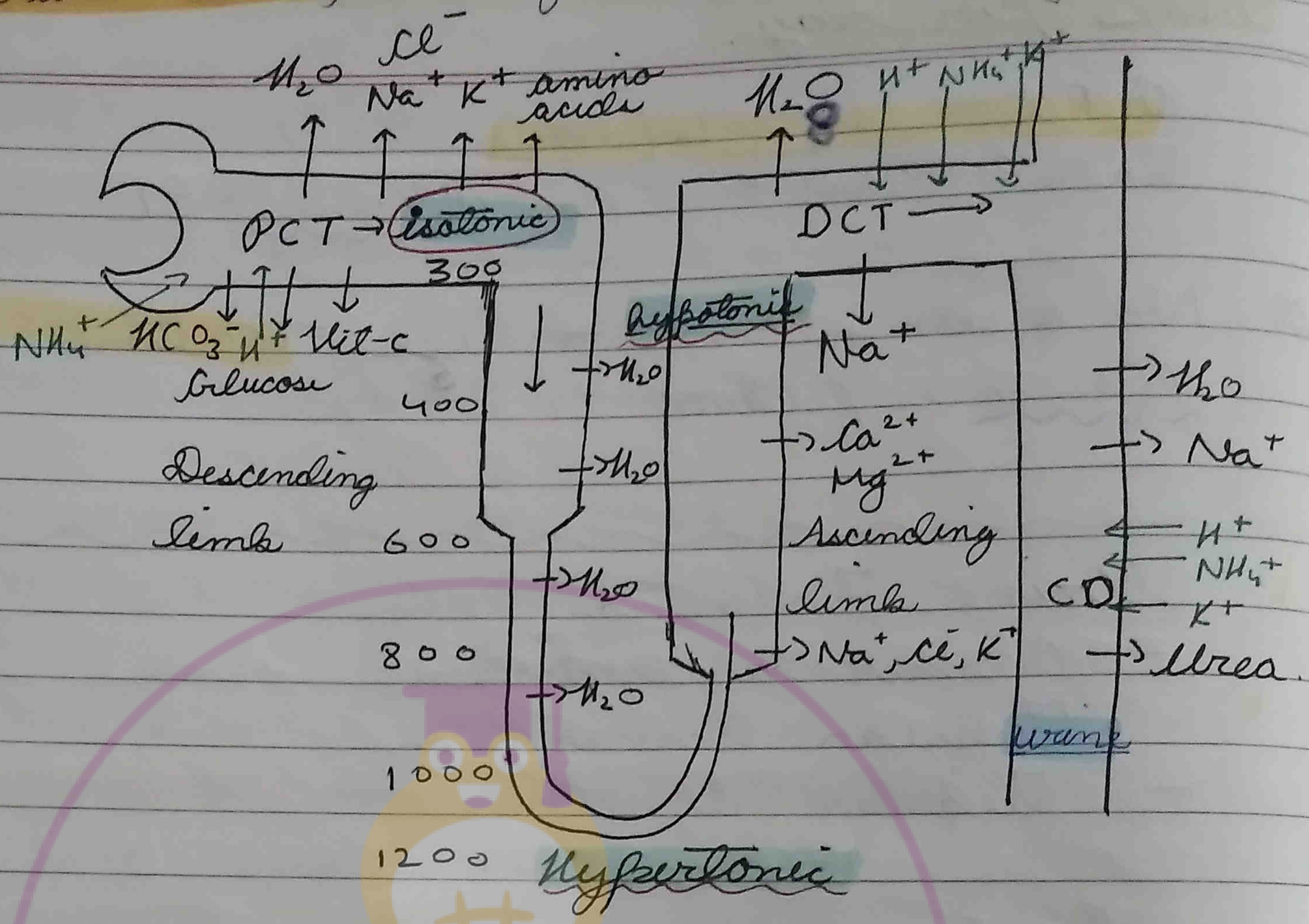
1 High Threshold Substances : These substances are maximally reabsorbed.
e.g Water, Glucose, Amino acids, Na^+, Cl^-

- Renal Threshold : upper limit upto which a substance is reabsorbed from glomerular filtrate.
  e.g Glucose 180 mg/dL

2 Low Threshold substances : These substances are partially reabsorbed e.g Urea, Uric acid

3 Non - Threshold substances : these substances are (not) reabsorbed
e.g Creatinine, Hippuric acids, ★ Inulin.

- Urine can be concentrated upto 4 times than human blood.
- Kidneys are also responsible for maintaining pH of blood.



PCT: 60% of the glomerular filtrate is reabsorbed i.e H_2O, Na^+, Cl^-, HCO_3^-, Glucose, Vitamin-C, Aminoacids, K^+, little amount of Urea and Uric acid.

- Descending limb: permeable to water only
  - H_2O (reabsorbed)
- Ascending limb: permeable to ions only
  - Na^+, Cl^-, K^+, Mg^{2+}, Ca^{2+}
- DCT: Conditional reabsorption of
  - Water — ADH
  - Na^+ — Aldosterone
  - Ca^{2+} — Parathyroid hormone
- Collecting Duct (CD): Conditional reabsorption of H_2O, Ca^{2+}, Na^+.
  - Shows permeability for Urea.

☆ Glomerular filtrate and filtrate in PCT are isotonic to plasma

- **Tubular Secretion**

Certain substances are extracted from peri-tubular capillaries and added to filtrate

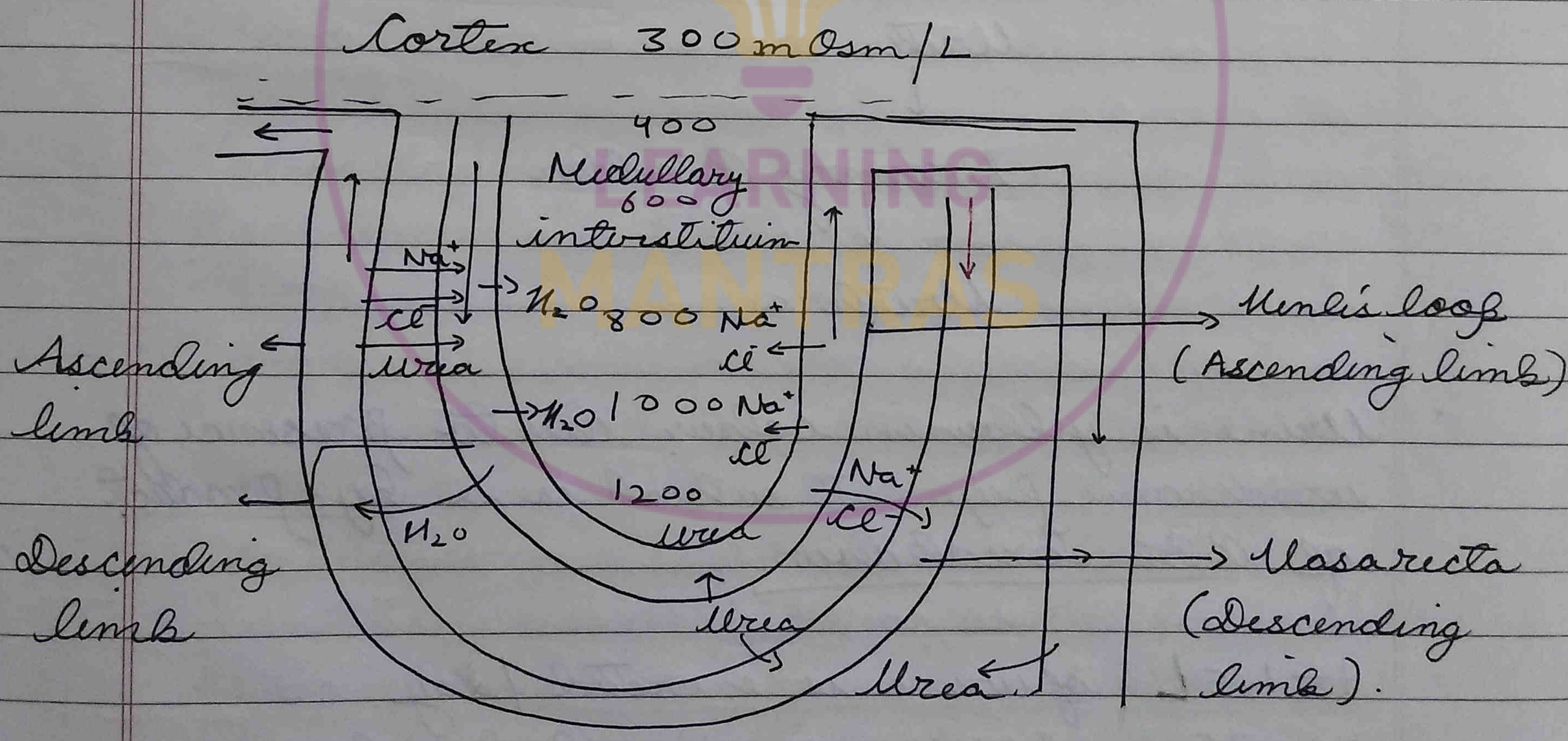
K^+, H^+, NH_4^+, Creatinine, Hippuric acid, drugs.

PCT, DCT and CD are concerned with secretion.

Counter Current Mechanism

Mechanism which helps in concentrating the urea by maintaining high concentration of NaCl and urea in the medullary interstitium.

It consists of - Loop of Henle and Vasa Recta.



- Henle's Loop forms counter current Multiplier. By actively transporting Na^+ and passively transporting Urea.

Vasa Recta is freely permeable to H_2O, NaCl

- Higher the intake of proteins, higher is the formation of urea hence concentration of medullary interstitium is high and the urine becomes more concentrated

and Urea.

Urine

Collecting Ducts
↓
Duct of Bellini
↓
Minor Calyx
↓
Major Calyx
↓
Renal Pelvis
↓
Ureter
↓
Urinary Bladder
↓
Urethra.

- Urine is yellow in colour due to presence of urochrome pigment which is a by-product of RBC breakdown.

1 – 1.5 L of urine is excreted / day
25 – 30 g of urea is removed per day.
pH = 6 (4.2 – 8.2)
Heavier than water
95.1. of urine consists of water and rest 5.1. contains Urea, Uric acid, K^+, K^+, NH_4^+, SO_4^{2-}, PO_4^{3-}, oxalates, Creatinine, Hippuric acid.

- Ketone bodies are formed due to fat breakdown.
☆1 : Due to damage to Malpighian corpuscles

- Abnormal Constituents

- Glycosuria / Glucosuria → Glucose in urine, occurs due to Diabetes mellitus.

- Ketonuria → Ketone bodies in urine due to Diabetes mellitus, Starvation.

- ☆1 Albiminuria → albumins in urine due to Glomerulo nephritis in which if inflamation is present in glomerulus and nephron.

- Haematuria → Blood in urine.
Usually seen in cases of Kidney stones / Renal calculi.

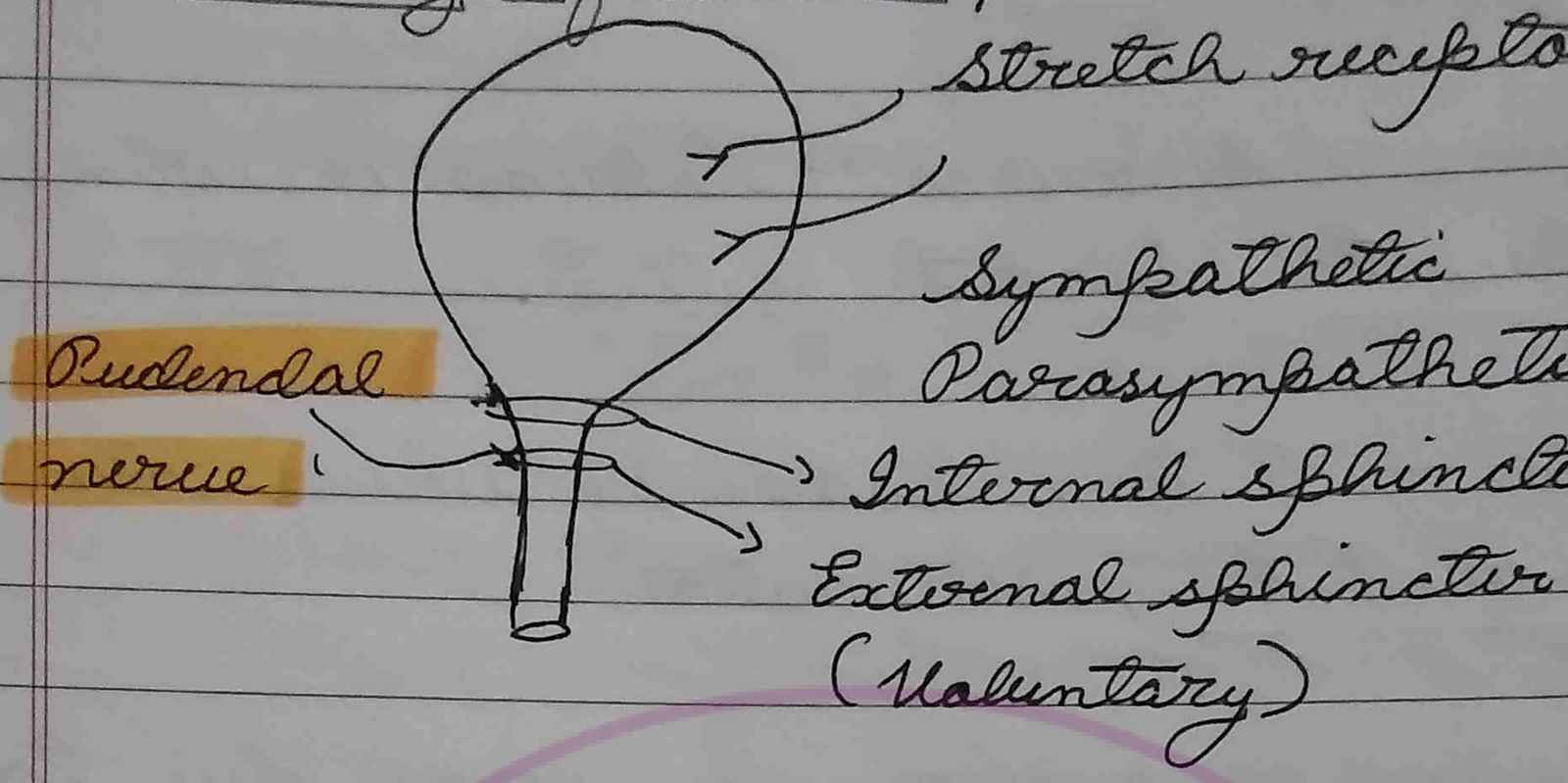
- Haemoglabinuria → Haemoglabin in urine due Haemolysis (Rupture of RBCs).

- Pyuria → Pus cells in urine caused due to infection in kidney

- Xanthinuria → xanthine in urine
Xanthine is an intermediate formed during purine metabolism.
It is caused due to deficiency of the enzyme xanthine oxidase.
It can lead to formation of stones known as xanthine calculi.

- Pudendal nerve acts on external sphincter because of (active mode) it remains constricted.

- Voiding of Urine / Micturation



- Sympathetic Nervous System
Responsible for filling of bladder.
  - Bladder is relaxed
  - Urethral sphincters are constricted.

- Stretch receptors are stimulated on filling of bladder.
  - Pudendal nerve is inhibited.
  - Sympathetic nervous system is inhibited.
  - Parasympathetic nervous system is activated.
  - Bladder is contracted, sphincters are relaxed and urine passes out of urethra.

- Micturation is controlled by micturation reflex centre present in pons and connected to the cerebrum.

- Accessory Excretory Structures

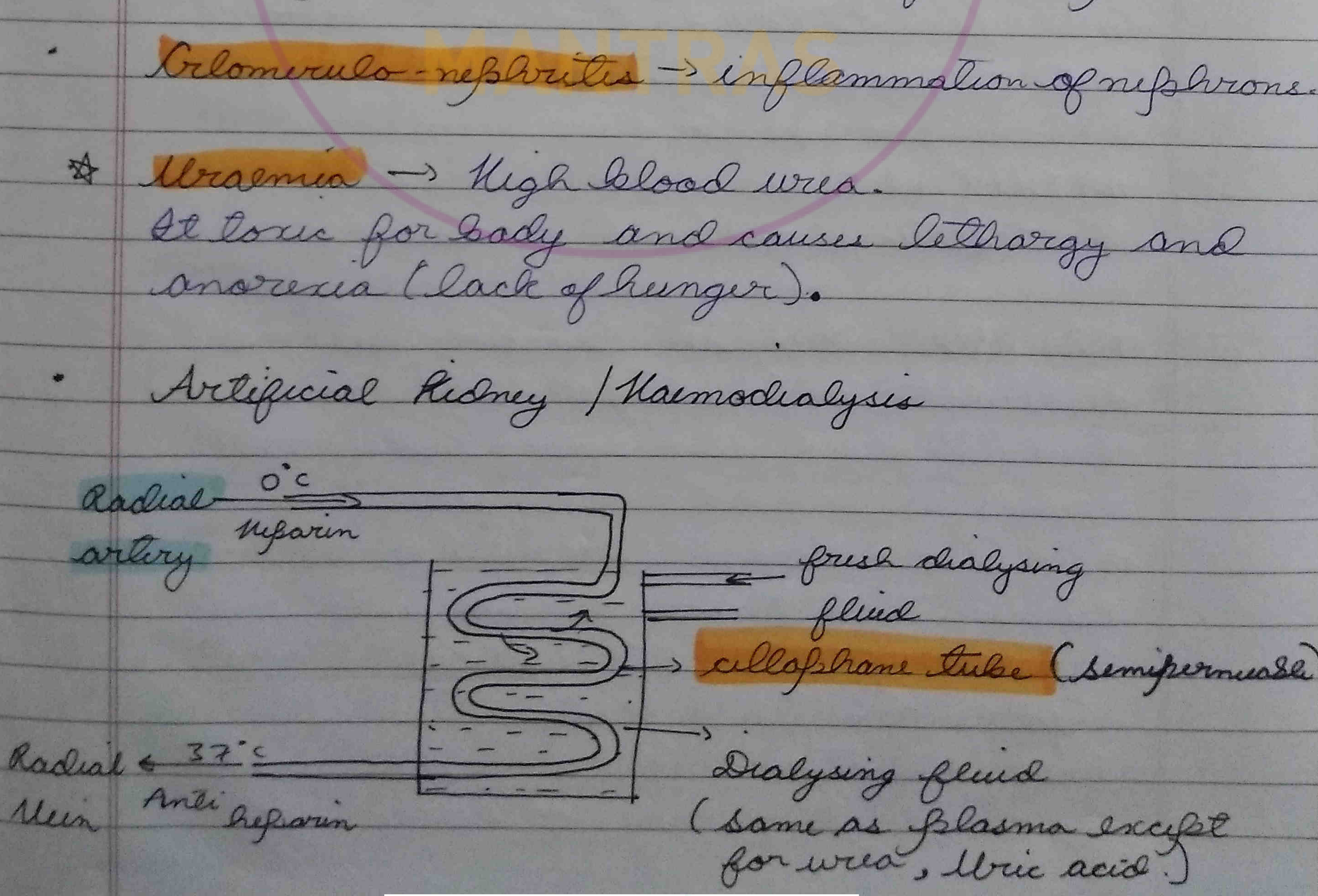
(i) Liver → Detoxification of substances present in food.
Synthesis of urea.

- nephrons are formed only once.
- nearly 18 litres of CO_2 is removed per day

- Lungs → Removes CO_2 and water vapour.
- Sweat → Water, little amount of urea, lactic acid.
- Sebum → secretid from oil glands containing hydrocarbons, waxes and sterols.

- Disorders of Kidney -
- Each kidney has 1 million nephrons.
- ✡ Cystitis → inflammation of urinary bladder.
- ✡ Pyelonephritis → inflammation of renal pelvis.
- Glomerulo-nephritis → inflammation of nephrons.
- ✡ Uraemia → High blood urea.
  It toxic for body and causes lethargy and anorexia (lack of hunger).

- Artificial Kidney / Haemodialysis



- Kidney Transplant → Matching donor is needed and person has to take Cyclosporine which is an immunosuppresant drug.