Lec 1

The Urinary System

- 2 kidneys each supplied by Renal artery & vein, which do most of the work of the system
- 2 ureters send urine to bladder for storage until micturation through the urethra

Function

filter waste from blood

- through 3 processes : filtration, reabsorption, & secretion
- works w/ CVS, endocrine, & CNS
- elimination of :

  amonia & urea → from amino acids

  uric acid → from nucleic acids

  creatine → from muscles

  end products of other metabolites

- & exit the body throug excretion

Conserves valuable nutrients

- glucose, amino acids & others are maintained in body through reabsorption

* Kidney can undergo gluconeogenisis w/ glutamine

Regulates Ion Plasma levels

- Regulates amount of Na, K, Cl, by ↑ or ↓ amount excreted

Regulates Blood PH

- Kidney works w/ lungs & regulates H^+ & bicarbonate

ion excretion

Regulates RBC Production

- if blood O_2 levels are low, Kidney releases erythropoietin to ↑ RBC

Stores & Excretes Urine

- Storage by bladder, excretion through urethra

Produce & Secrete hormones

- activation of Vit D into Calcitriol
- Renin → regulation of BP & Na^+, K^+
- Prostaglandins/Kinin → bradykinin is vasoactive to control Renal Blood flow (BF)
- erythropoeitin → RBC formation

Kidney Structure

- Renal cortex → dense & light color; covered by capsule
- Renal medulla contains Renal pyramids, separated by Renal columns ... the tip of the pyramid is the Renal Papilla
- papillary duct empties urine into minor & major calyces of the renal papilla, then into the renal pelvis (large container), then into ureter
- Hilum contains Renal artery & vein

Major Blood Vessels

- each kidney has 1 artery & vein
- Renal artery starts big, then gets smaller to supply all of kidney

Small branch called arcuate artery gives rise to afferent arteriole in the nephron that then creates the glomerulus then the efferent arteriole which then create peritubular capillaries

* no venules

- Renal vein starts as small venules then make large veins

Nephron Structure

- balloon structure called bowmans capsule surrounds the glomerulus, & together are called the Renal Corpuscle
- The capsule is attached to Proximal Convoluted Tubule (PCT) which leads to the loop of henle (LH)(a hairpin loop)
- LH has thin descending & ascending limb, then thick ascending limb
- Then forming the distal convoluted tubule (DCT) → Connecting tubule → collecting tubule → the to the collecting duct that empties into renal papilla

* each kidney has 1 million nephrons ... 2 types:

Cortical nephron

- the majority
- in the cortex & short ... penetrates outer part of medulla
- forms urine & contains peritubular capillaries

Juxtamedullary nephron

- between cortex & medulla, extend deep into medulla, so

they are longer & penetrates papilla

- Vasa Recta (instead of peritubular capillaries) w/ venous & arterial capillaries that lie parallel to each other
- mainly concentrates urine

Urine formation Mechanism

Blood goes to afferent arteriole → glomerulus for filtration → efferent arteriole → peritubular capillaries for reabsorption into body & secretion in opposite direction → excretion

* Excretion = filtration - Reabsorption + secretion

Filtration

- Passive* function depending on hemodynamic forces
- variable & not selective* (except for proteins)
- filters 20% of plasma, 80% unfiltered

Reabsorption

- Active process* through sective transport
- highly variable & selective *
- electrolytes & nutritional substances almost completely reabsorbed, waste products poorly reabsorbed

Secretion

- highly variable, depends on what needs to be secreted
- Rapidly excretes waste (H^+, drugs, toxins)

Renal Corpuscle Histology

Bowmans capsule

- outer: simple squamous epithelium

- Inner : Podocytes around glomerulus
- Capsular space: btwn the two structures filled w/ filtered fluid

Juxtaglomerular cells

- modified smooth muscle of afferent & efferent arterioles next to the macula densa
- part of juxtaglomerular apparatus formed by macula densa

Macula Densa Cells

- final part of thick ascending LH & DCT

Mesangial Cells

- Contractile supportive cells in the cleft btwn afferent & efferent arterioles
- regulate surface area for filtration

Filtration Membrane

- Basal lamina is negatively charged so it repels (-) charged molecules like albumin
- Podocytes have foot processes (pedicles) that wrap around glomerular capillaries forming slit membrane → prevents passage of medium sized proteins

Renal Tubule histology

- PCT → simple cuboidal w/ brush border
- LH → thin : simple squamous , thick : cuboidal
- DCT → simple cuboidal
- last part of DCT & collecting duct → simple cuboidal

w/ principle cells (ADH & Aldosterone receptors) &

Intercalated cells (Blood PH regulation)

Lec 2

I will only add new info, I will not Restate anything already written ♡ enjoy

Filtration of different Substance

- In order to get rid of waste & keep necessary nutrients, Kidney filters different products in different ways

water

- 180 L filtered / day, 179 reabsorbed, 1 L excreted

Glucose

- Same amount filtered is also Reabsorbed → no excretion
- glucose only in urine if there is disease (diabetes)

Creatine

- waste product, so nothing is reabsorbed
- 1.8 L filtered, 1.8 L excreted

Types of filtration

Filtration only

- rare ... no reabsorption or secretion

Filtration & Partial Reabsorption

- water & most electrolytes get partially reabsorbed & part will be excreted
- excretion = filtration - Reabsorption

Filtration w/ complete Reabsorption

- glucose, amino acids, valuable substances

- no excretion

Filtration w/ Secretion

- waste products, metabolites, drugs, acids & bases to maintain pH
- no reabsorption
- high urinary excretion (excretion = filtration + secretion)

Factors Affecting filtration

- Filtration is affected by partical size (b/c of slit membrane) & charge (b/c of basement membrane) & is a passive process
- polycationic molecules = highest filterability
- polyanionic molecules = lowest filterability, & as size ↑, filtration can stop
- neutral molecules depends on size → the smaller, the more filterability

Glomerular filtration

- we test function of filtration by glomerular filtration rate (GFR)
- normal rate = 180 L / day or 125 ml / min
  - differences btwn sexes, age, & weight

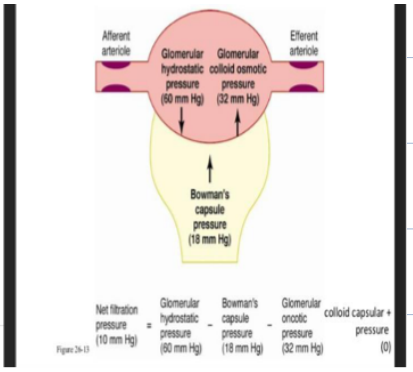
* we only have about 5 liters of blood ... so how 180L ?

- Plasma is filtered 60 times / day, which is important to get rid of waste, monitor osmolarity, electrolytes, & BP
- Glomerular filtrate composition is the same as plasma except for large proteins

- Filtration fraction (FF) is GFR / Plasma flow Rate
  - normally 20% → 20% of renal plasma flow filtrates
- Plasma flow rate → how much plasma enters both kidneys & perfuse the nephron / min

....

- Blood coming from heart has MAP of 100 mmhg & once it enters afferent arteriole it ↓ to 55 mmhg → known as glomerular blood hydrostatic pressure
- once this enters the glomerulus, it pushes whateve fluid already present into bowmans capsule as filtered fluid
  - the fluid in bowmans capsule has capsular pressure of 15 mmhg, & works in opposite direction of glomerular hydrostatic pressure
- The proteins that cant cross the membrane into bowmans capsule start to build up pressure → colloid osmotic pressure (oncotic pressure) & also go in opposite direction of filtration
  - 30 mm hg



* no protein in bowmans capsule, so oncotic pressure = 0
- glomerular pressure = +55, capsular = -15, oncotic = -30 ... So net filtration pressure = +10 in favor of filtration

* FF = GFR / RPF

  20% = 125 / RPF ... RPF = 625 ml

- 625 ml is normal plasma flow rate

- Renal plasma flow & blood flow are not the same
  - 55% of blood is plasma, so 625/.55 = 1140

* So **Renal blood flow = 1140 ml/min**
  - this is **22.8% of cardiac output** (b/c we have 5L of blood)

- So kidney recieves 20-22% of CO, not to be used, but only b/c GFR needs this amount

Clinical Significance

- if **protein leaks** outside barrier = **proteinuria** & early detection is important especially in at risk pts.:
  hypertension, Diabetes, Pregnancy, & annual check ups b/c renal disease can be silent

- **damage to glomerulus** may allow more proteins to enter which will ↑ colloid pressure, drawing more water to the capsule
  - proteins lost in urine, blood volume ↓, interstitial fluid ↑ = **Edema**

* these occur from damage to endothelium, basement membrane, & podocytes

Regulation of Glomerular filtration

High GFR

- more than 125 ml/min = **not enough time to reabsorb** necessary substances so we will lose H_2O, glucose, amino acids

low GFR

- leads to an ↑ in harmful waste products b/c reabsorption

will be more efficient than filtration

Determinants of GFR

Net filtration Pressure

- Direct relationship to GFR
- GFR = net filtration x Kf
  - Kf = filtration coefficient = 12.5 ml or 4.2 ml/100g
  - 125 ml = 10 mmhg x 4.2
    - 4.2 = 400x greater than many tissues
- damage to capillaries & BM thickness can ↓ Kf & GFR
  - for ex. Diabetic Nephropathy → ↓ in Kf & GFR due to damage of podocytes, endothelial cells & ↑ thickness of BM

Bowmans Capsule & hydrostatic Pressure (capsular pressure)

- filtration changes as a function of GFR due to pathology, not as a regulator * inverse relation to GFR
- GFR will be reduced due to:
  1) Tubular obstruction by stones, crystals or fibrosis → ↑ hydrostatic pressure → ↓ GFR
  2) Urinary Tract obstruction such as hypertrophy of cancer

Capillary oncotic Pressure

- inversely related to GFR *
- ↑ in oncotic pressure due to ↑ plasma protein or when GFR is higher than renal plasma flow, FF will increase, & oncotic pressure ↑
- as we move from afferent arteriole to efferent, more fluids are filtered, so oncotic pressure ↑ & net filtration pressure ↓

- microalbuminuria (more than 30 & less than 150 mg in urine) ↑ the risk of developing persistent proteinuria

- oncotic pressure is not easily regulated, so it does not regulate GFR, but is **a function of GFR** ... if GFR changes, oncotic pressure changes

Glomerular hydrostatic Pressure (GHP)

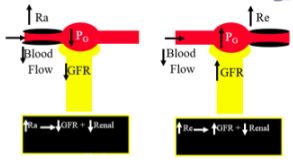
* **Physiologic Regulator**

- origin of this pressure is from the heart & is easily regulated

* **Direct Relationship to GFR**

- fluctuations in arterial pressure act differently in afferent & efferent arterioles

- in **afferent**, if I ↓ diameter of the arteriole, Resitance ↑, perfusion ↓, **GHP ↓ & GFR ↓**



- in **efferent**, ↓ in diameter = ↑ Resistance, & **↑ GHP, ↑ GFR**

* both cases blood flow ↓

→ but if resistance **↑ greater than 3x**, GFR will ↓ → Known as **biphasic behavior**

Why does biphasic behavior occur in efferent ↑ resistance?

- b/c too much ↑ in resistance will ↑ oncotic pressure which has a stronger affect on GFR than hydrostatic.

→ So **GHP is overcome by oncotic pressure**

* renal BF stays the same w/ ↑ Resistance of efferent below 3x, but BF ↓ w/ ↑ Resistance of afferent

* **So GFR depends on which factor overcomes the other**

Extra notes

$RBF = \Delta P / R$

ΔP = difference of Renal arterial & venous pressure

R = R afferent + R efferent + R vein

- Renal blood flow = 22 %
  - exceeds Kidney metobolic needs ... only needed because of GFR ... so high O_2 demand for renal function

* O_2 consumption related to tubular Na reabsorption
  - directly related to each other