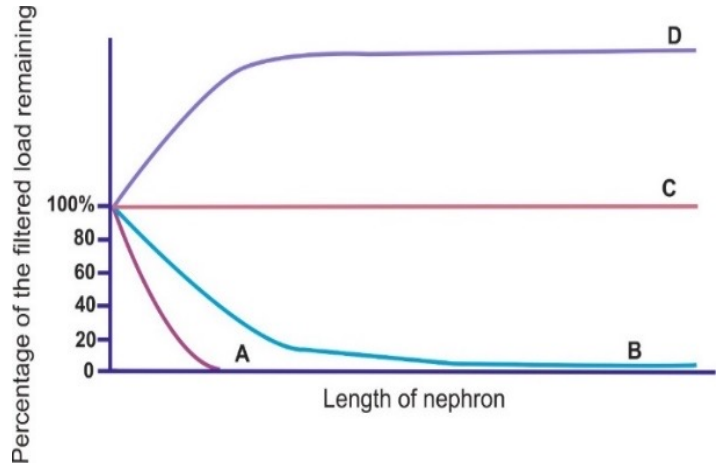
INTEGRATED RENAL-ELECTROLYTES

Renal Physiology

Clearance=

GFR=
RPF=
Filtration fraction=

Clearance: PAH > Creatinine > Inulin > Urea > Na > Glucose

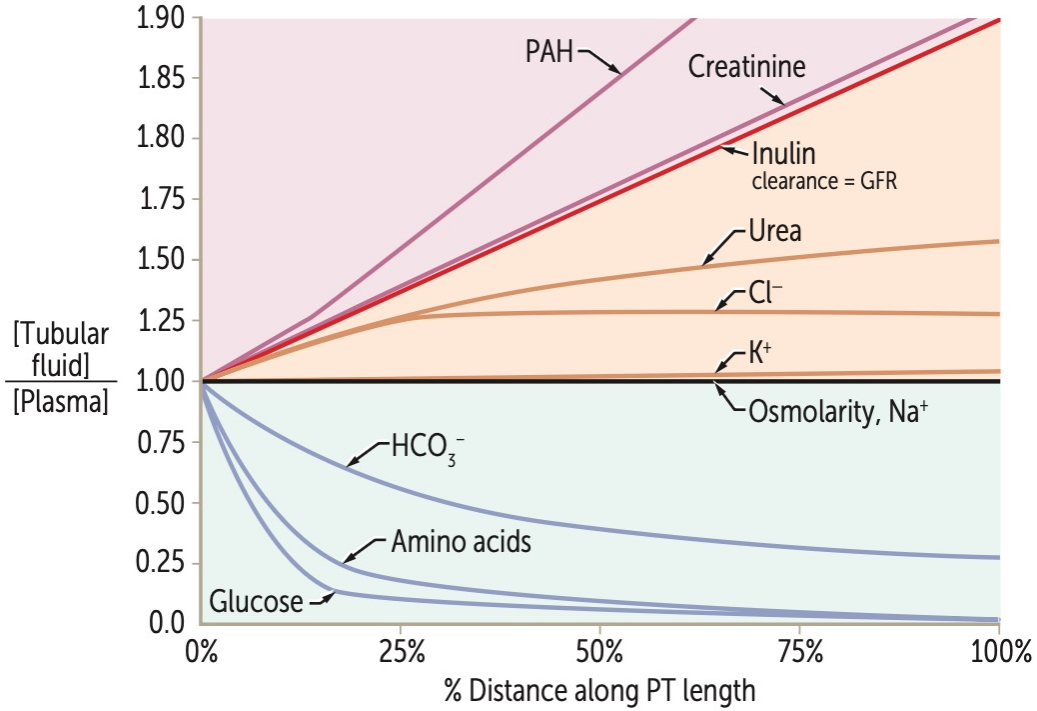


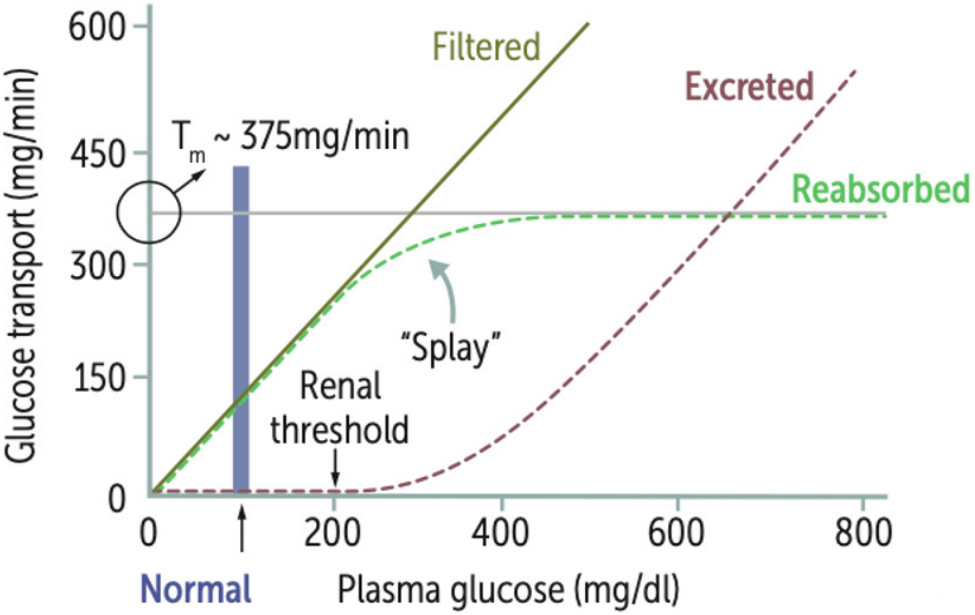
Counter-current :

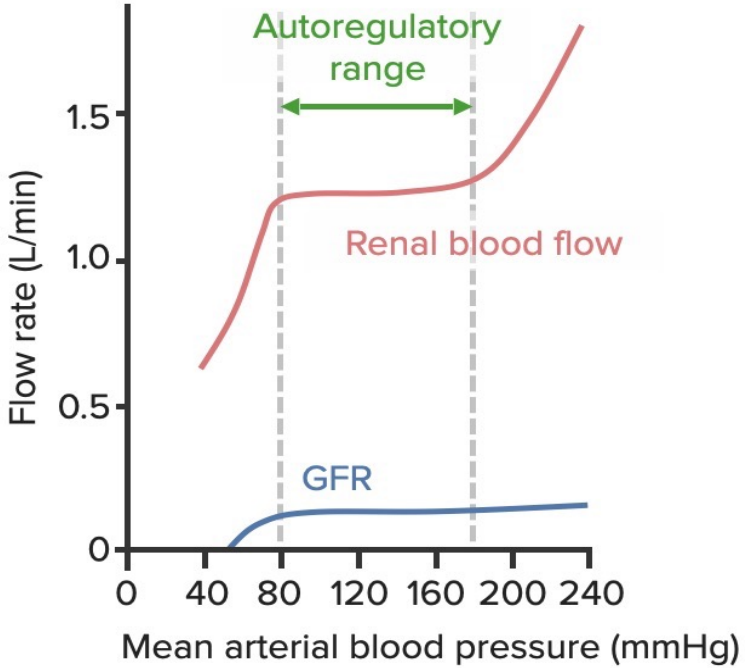
CC multiplier
CC exchanger:

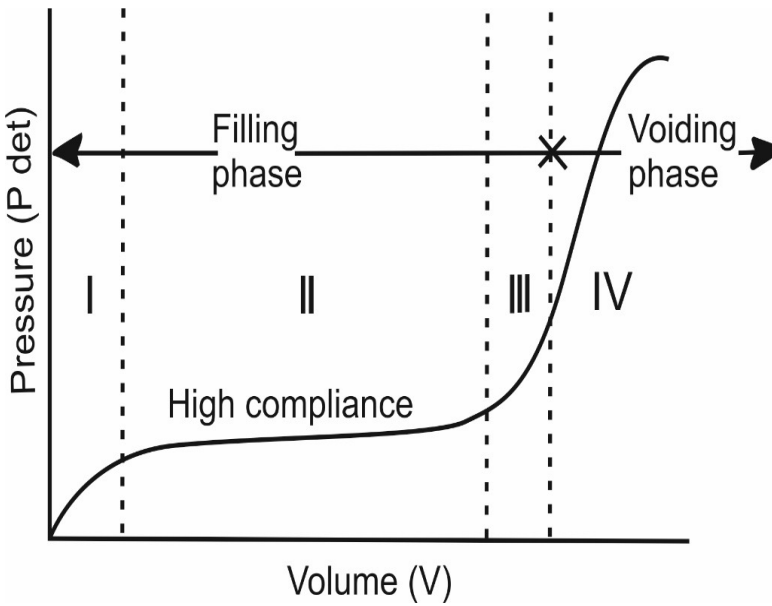
Macula Densa

Juxtaglomerular cells

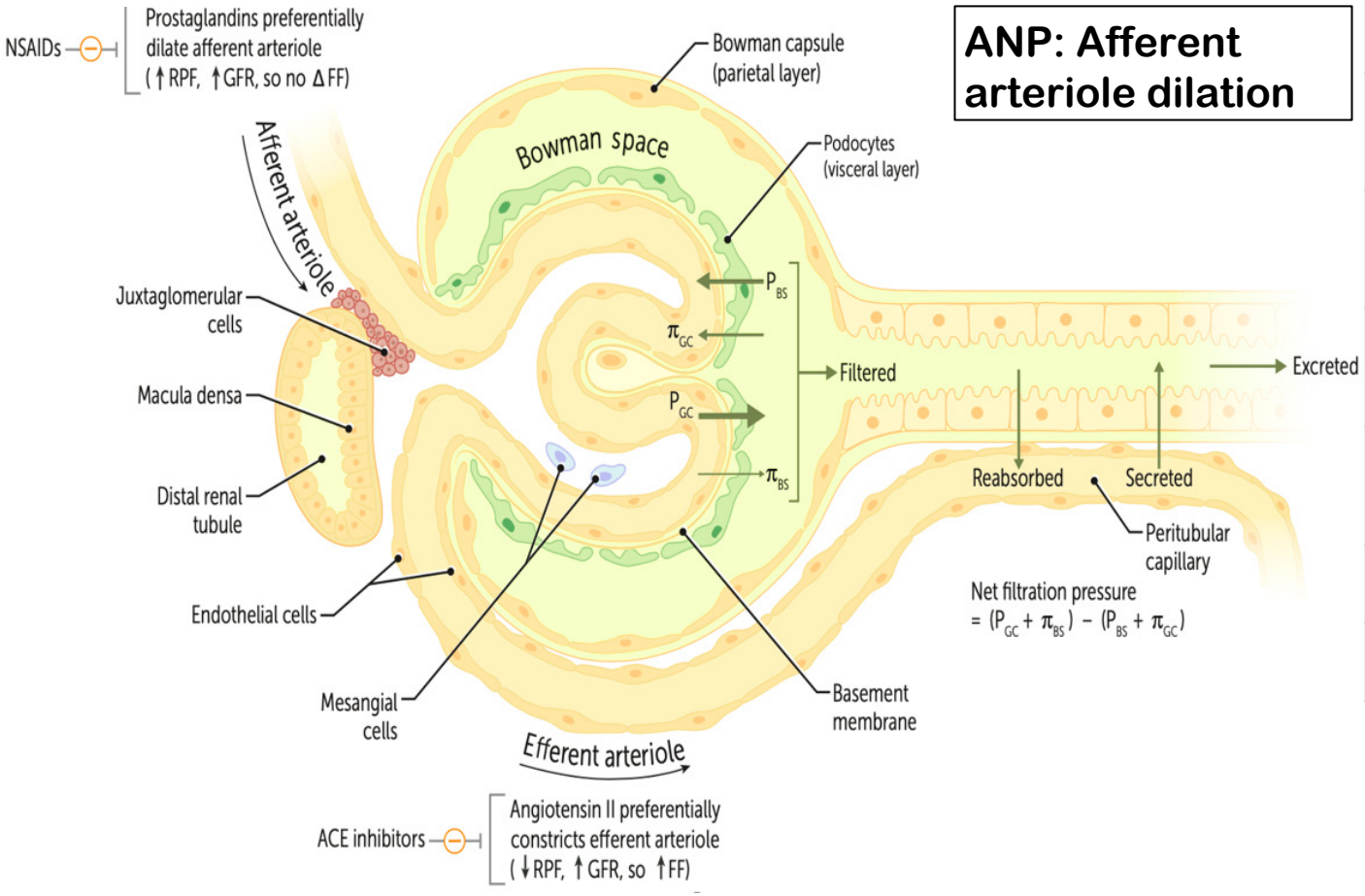



Glucose transport (mg/min)
600
450
300
150
0
Filtered
Excreted
Reabsorbed
T_m ~ 375mg/min
"Splay"
Renal threshold
0
200
400
600
800
Normal
Plasma glucose (mg/dl)


Autoregulatory range
Flow rate (L/min)
1.5
1.0
0.5
0
Renal blood flow
GFR
0
40
80
120
160
200
240
Mean arterial blood pressure (mmHg)

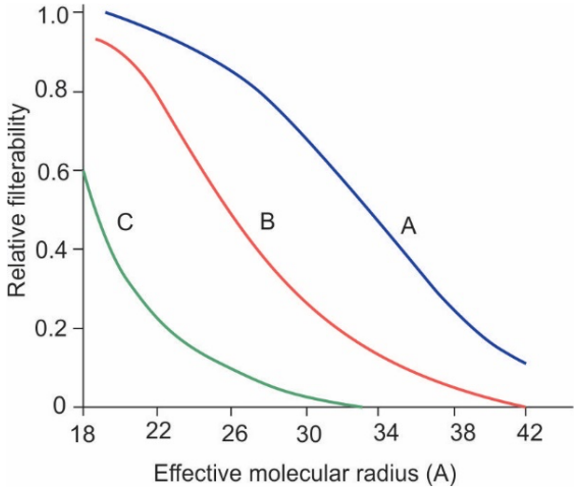

Pressure (P det)
Filling phase
Voiding phase
I
II
III
IV
High compliance
Volume (V)

Glomerular Filtration



ANP: Afferent arteriole dilation

	GFR	RPF	FF
Afferent arteriole constriction			
Efferent arteriole constriction			
High plasma protein concentration			
Low plasma protein concentration			
Ureter constriction			
Dehydration			

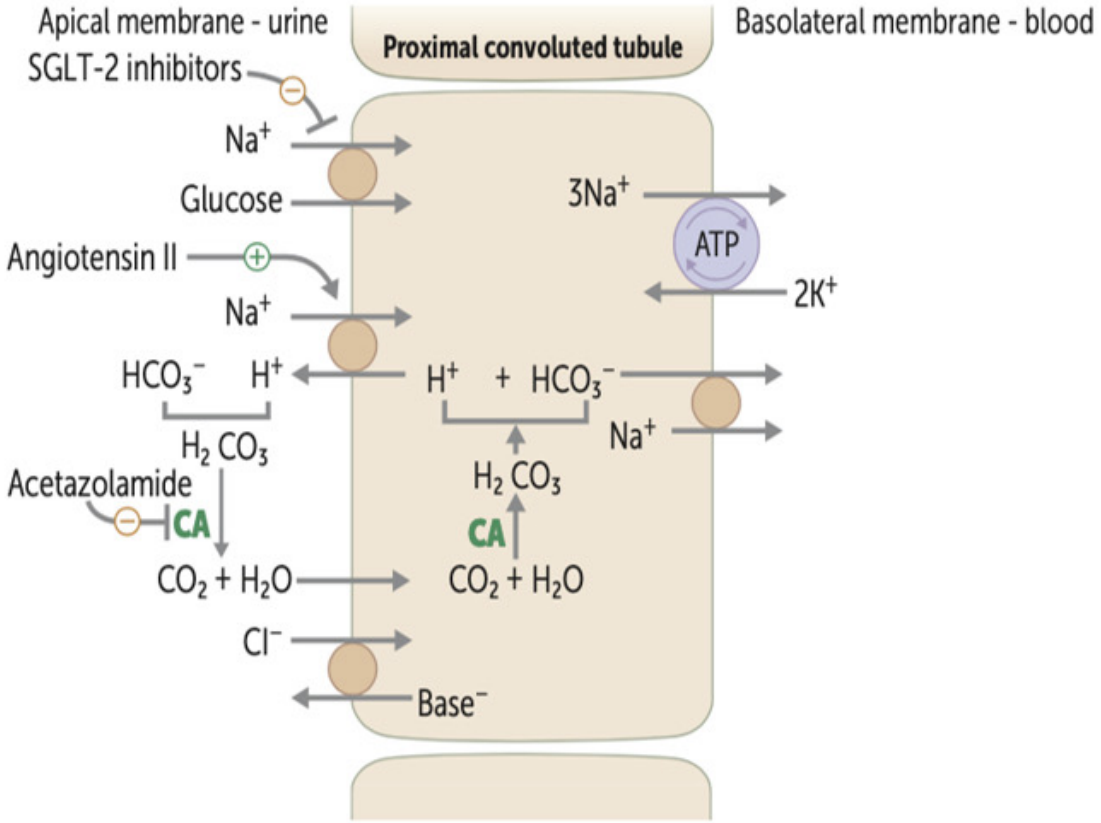


Glomerular filtration barrier:

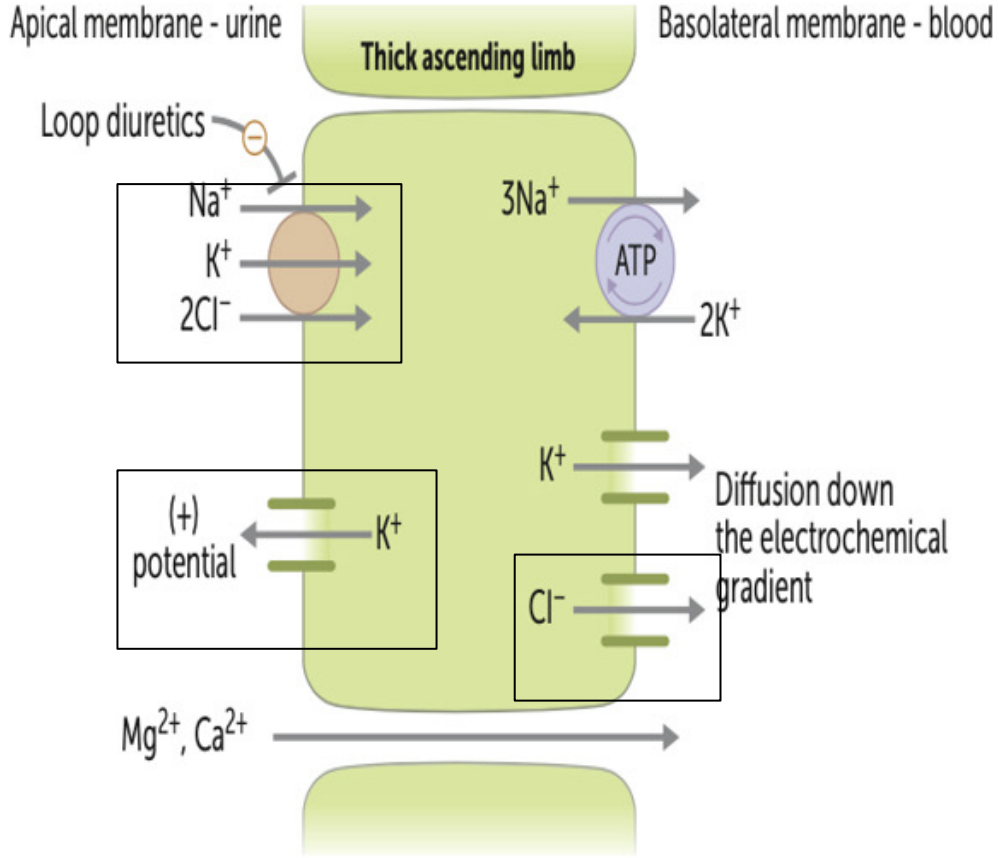
- Fenestrated capillary endothelium: 50-100nm
- Basement membrane with type IV collagen and heparan sulfate
- Podocyte foot processes Slit diaphragm pore size: ~ 4 nm

Dopamine ANP NO cAMP PGE2

Renal tubules

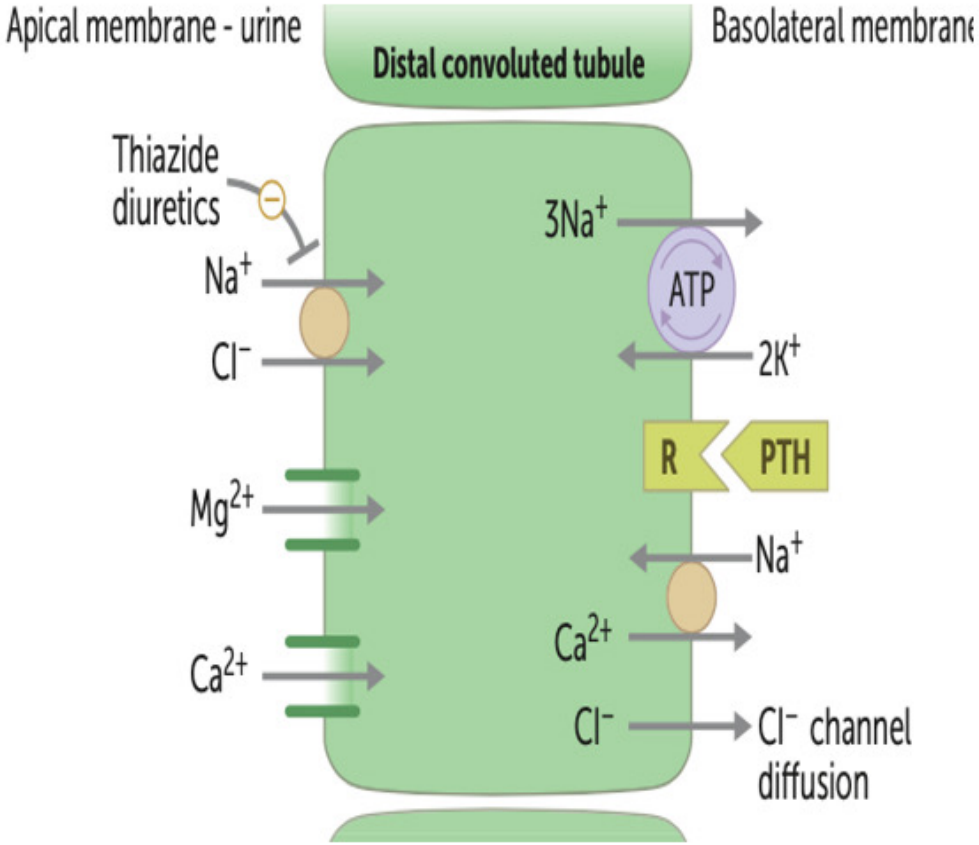


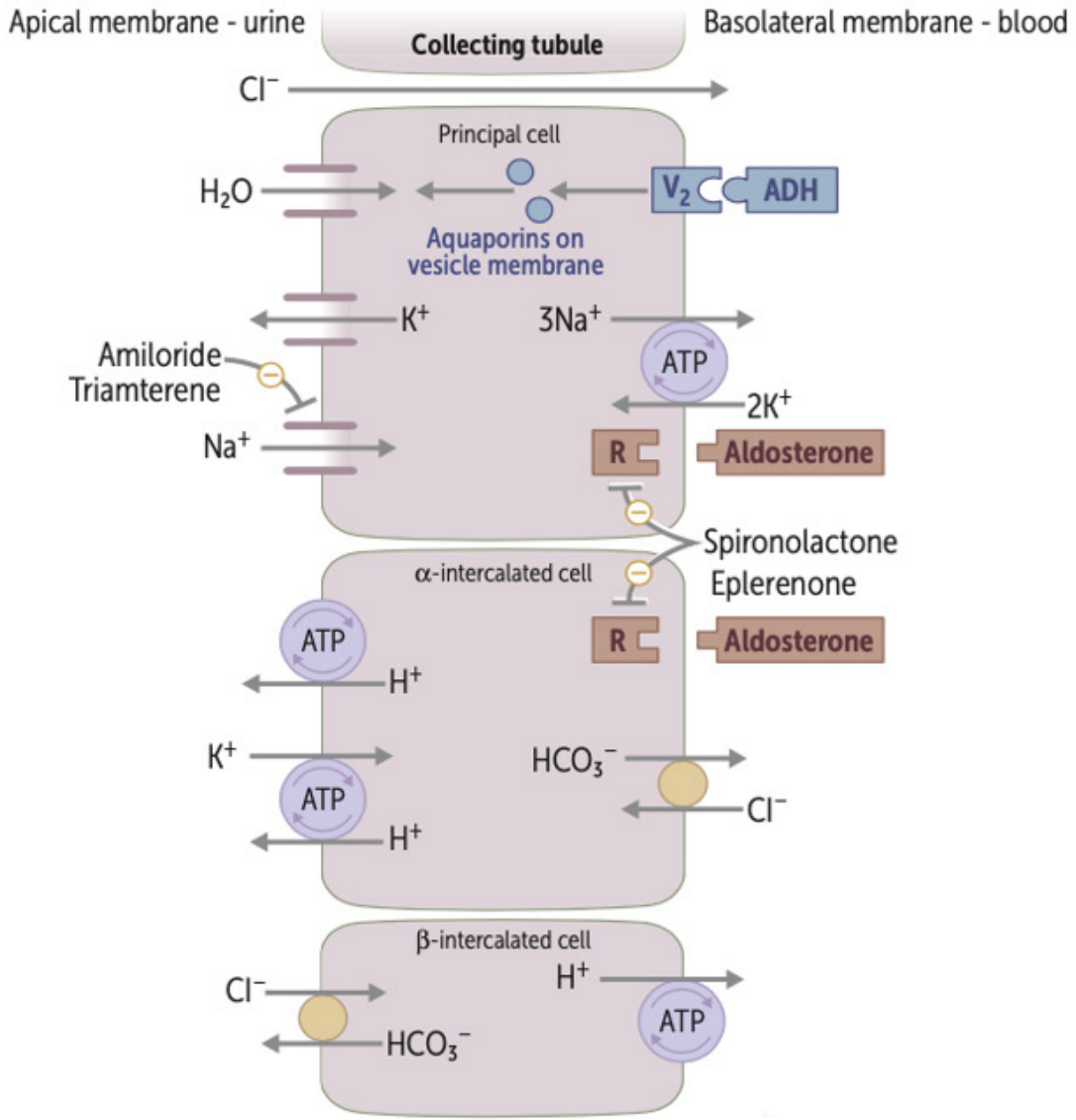
60% water



PTH:
PCT:
DCT:

THIN DESCENDING LOH:

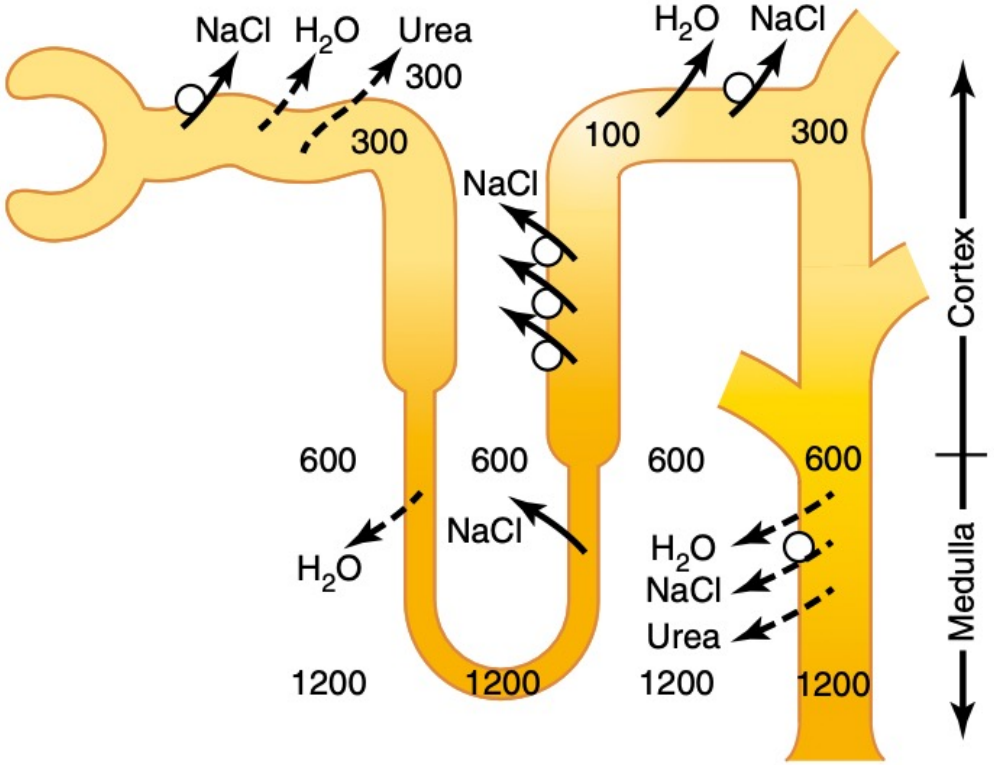




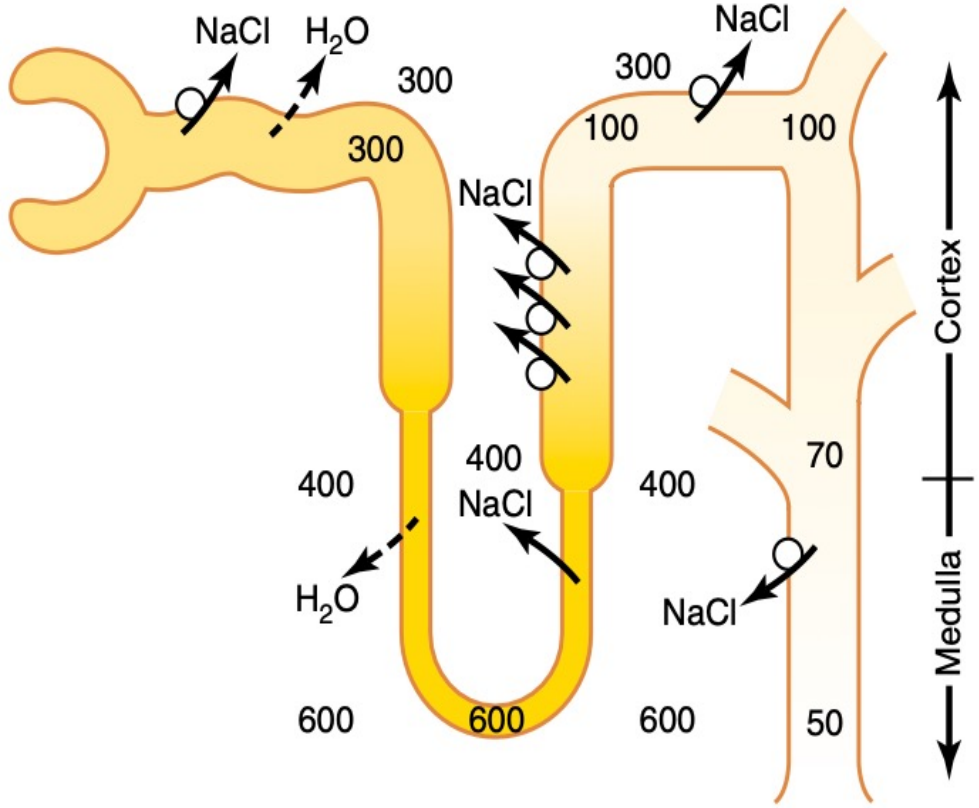
1-2% water absorption: no ADH
10% water absorption: ADH

The story of ADH

ADH normal



Absent ADH



Diuretics Pharmacology

Acetazolamide
S/E:
- Type 2 RTA
- Paresthesias
- NH3 toxicity
- Sulfa allergy
- Hypokalemia
- Calcium phosphate stones (insoluble at high urine pH)

DOC
- mountain sickness
- Familial hypokalemic PP

Thiazide
S/E:
- Metabolic alkalosis
- Hyponatremia
- Hyperglycemia
- Hyperlipidemia
- Hyperuricemia
- Hypercalcemia
- Sulfa allergy

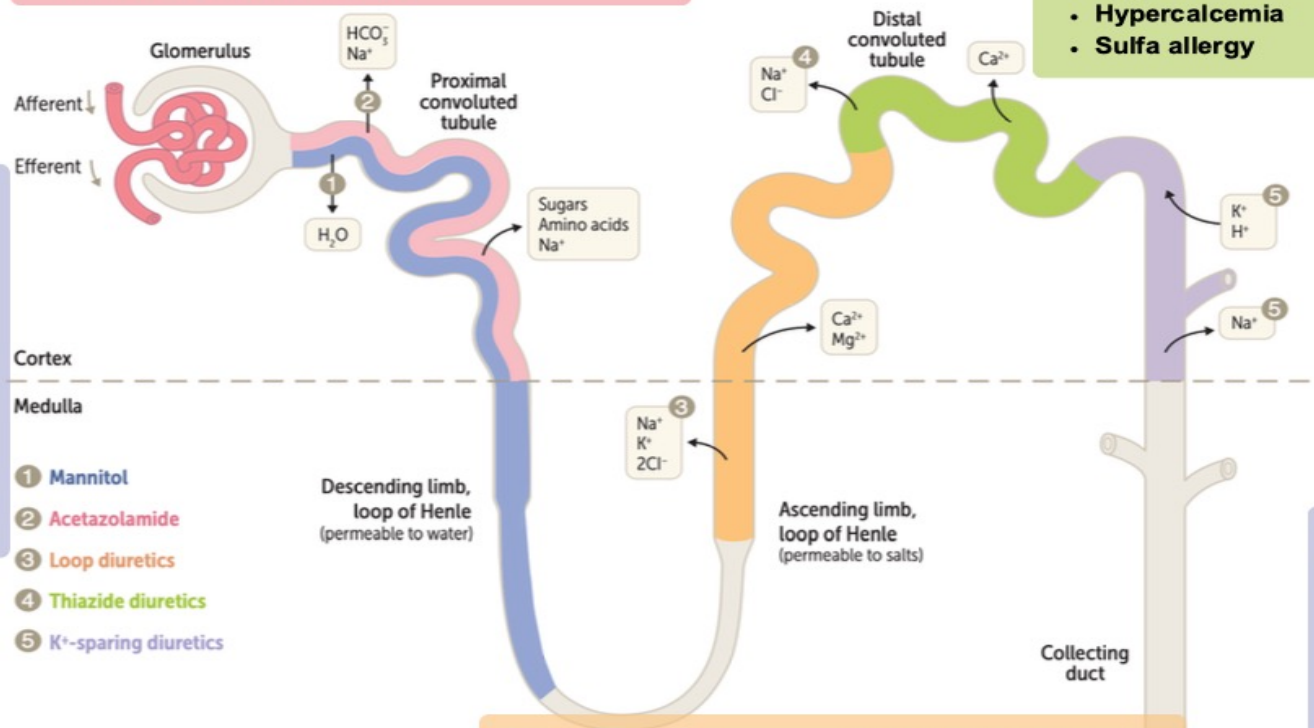
Chlorthalidone
Chlorthiazide
Indapamide
Metolazone

DOC:
ACG, DDS
Cerebral edema

Mannitol

S/E:
-Dehydration
-Hypo- or hypernatremia
-Pulmonary edema

C/I: Anuria, HF



Loop Diuretics
S/E:
- Ototoxicity
- DehydrationAllergy
- Sulfa allergy
- Metabolic Alkalosis
- Interstitial Nephritis
- Gout

Loops: Cardiogenic p.edema

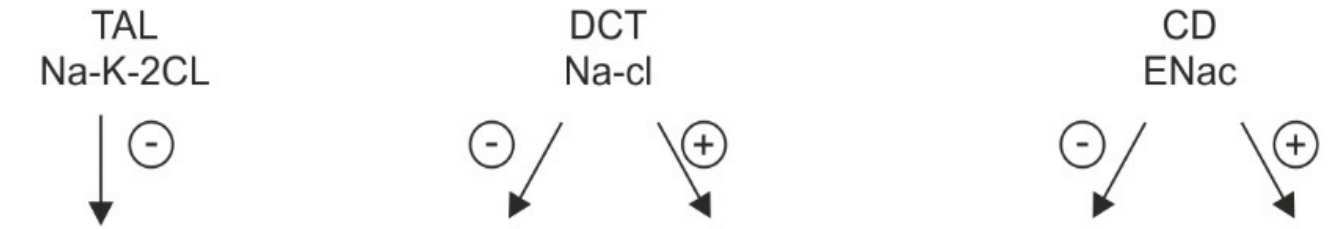
Torsemide:
Bumetanide:
Ethacrynic acid:

Potassium Sparing
S/E:
- Hyperkalemia
- Metabolic acidosis

DOC ascites, resistant HtN

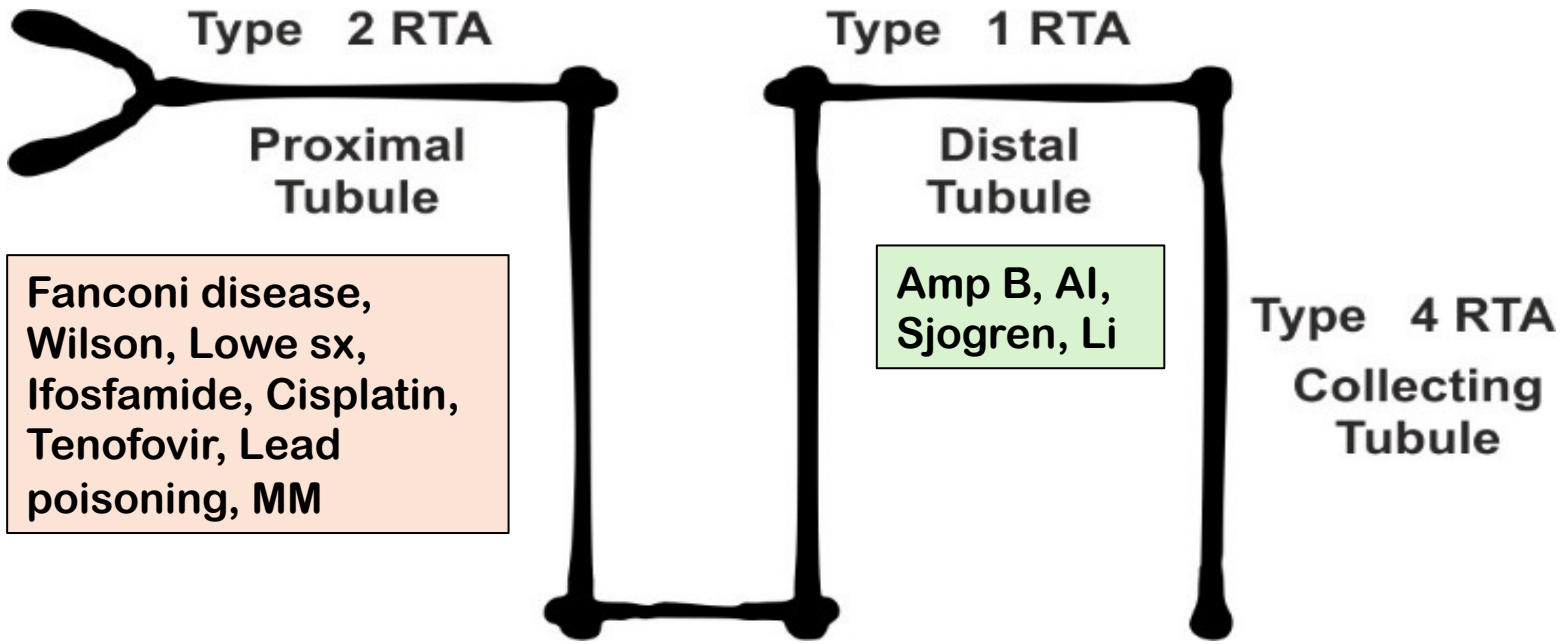
AMILORIDE:
DOC Li induced NDI, Liddle, cystic fibrosis

Tubular Disorders



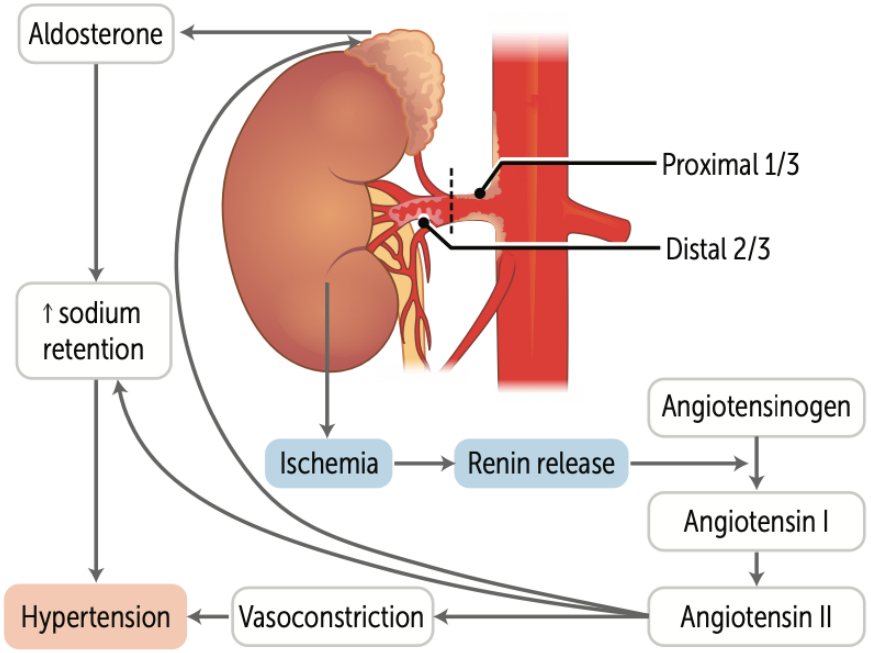
Dx					
BP					
K^+					
P^H					
Ca^{2+}					

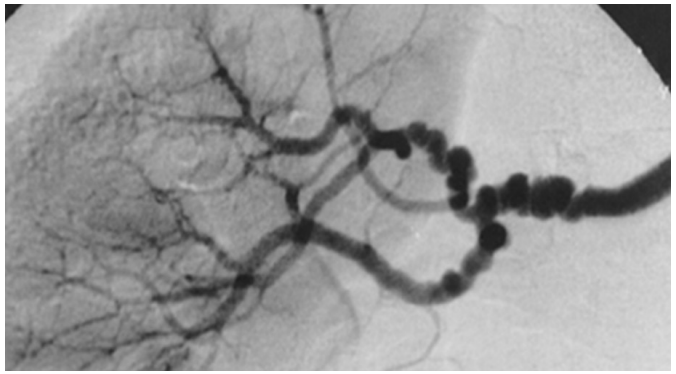
Renal Tubular Acidosis

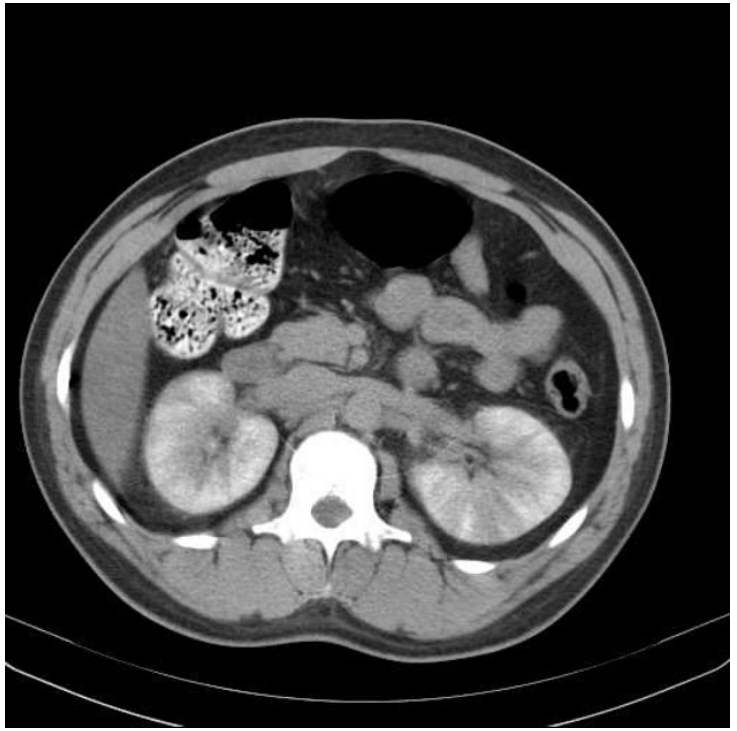


	K	Ca	Urinary pH	Nephrolithiasis

Reno-Vascular Diseases



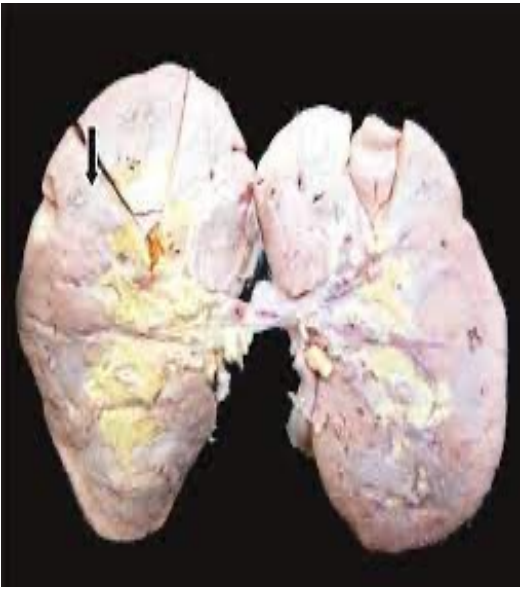


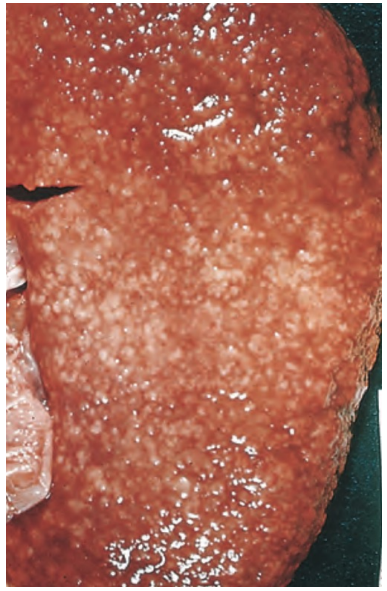
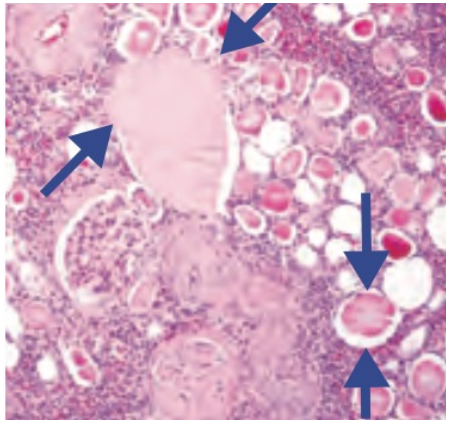
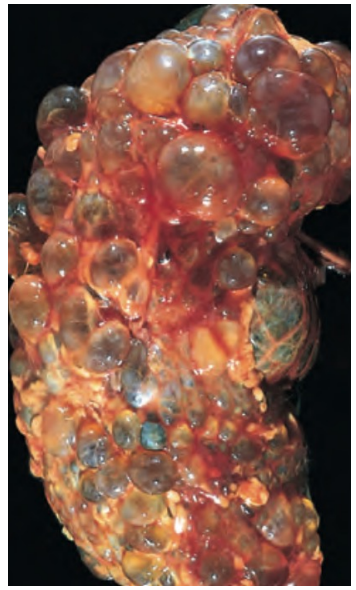


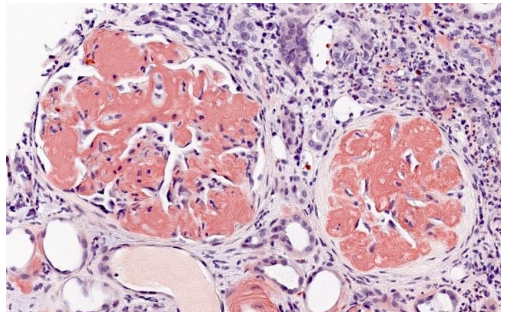
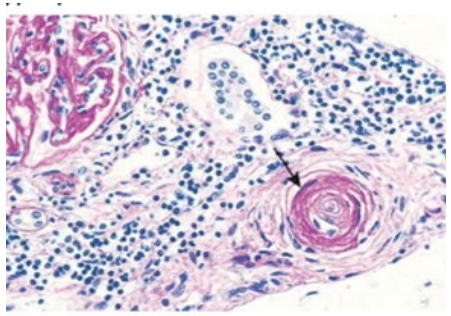
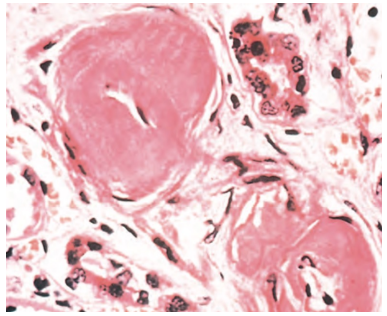
Renal - Segmental - Interlobar - Arcuate - Interlobular artery - Afferent arteriole - Glomerulus - Efferent arteriole - Peritubular capillaries

Acute ureteric obstruction/ pyelonephritis/ renal vein thrombosis

Renal Pathology



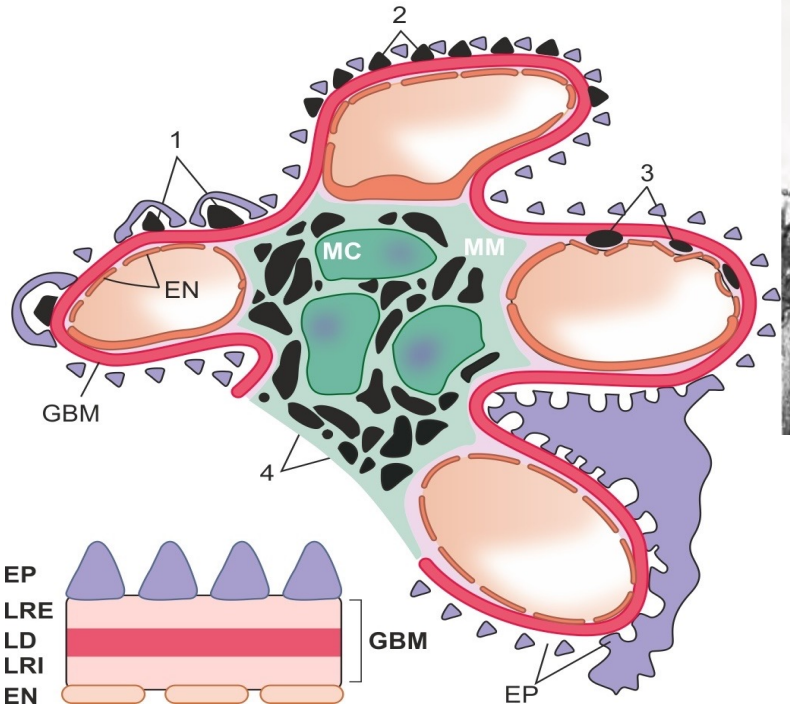
Chr 16,4: PKD1 & 2
Polycystin

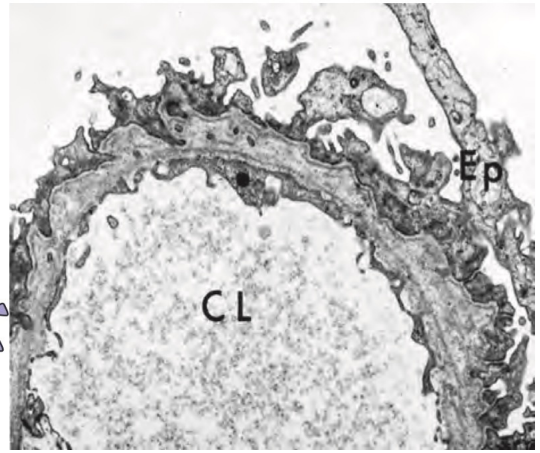
- Aortic dissection
- Berry aneurysm
- Diverticulosis

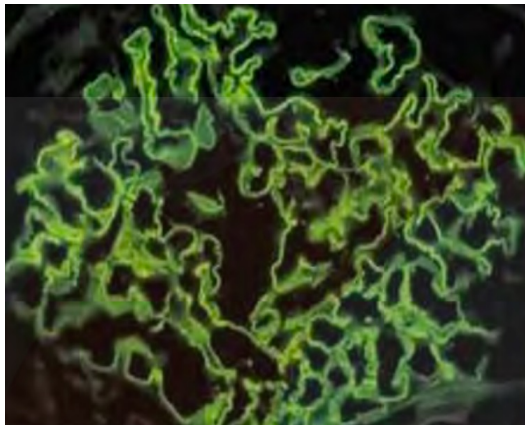
Chr 6: PKHD
Fibrocystin

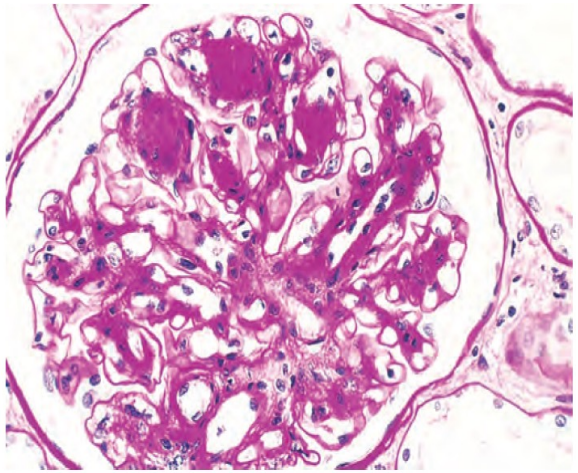
Congenital
hepatic fibrosis

Glomerular Diseases

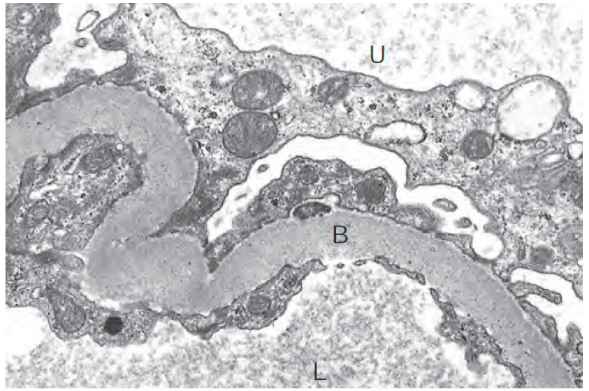








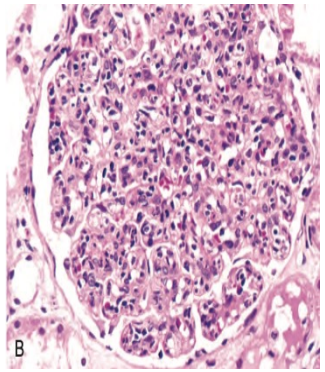
TYPE IV COLLAGEN

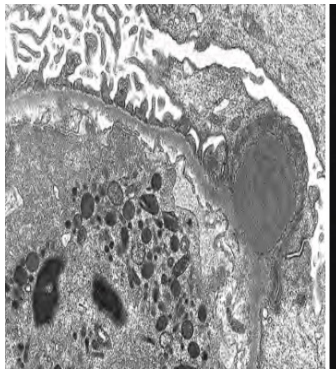


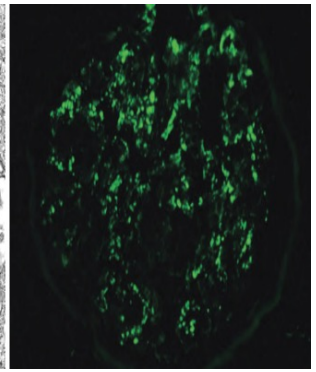
Nephritic Syndrome

Hematuria, Oliguria, Hypertension

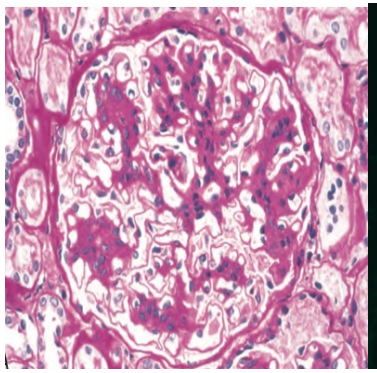
Child
Hematuria 10-21d after pharyngitis/impetigo
(strain 12,4,1)
Type III hysn
C3 transient low
70% Anti-DNase+
30% ASLO +

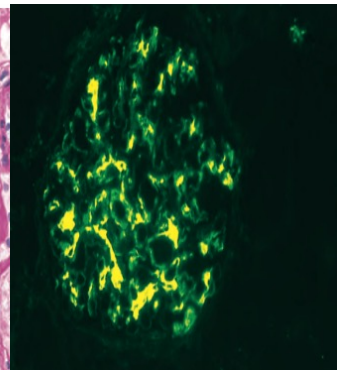




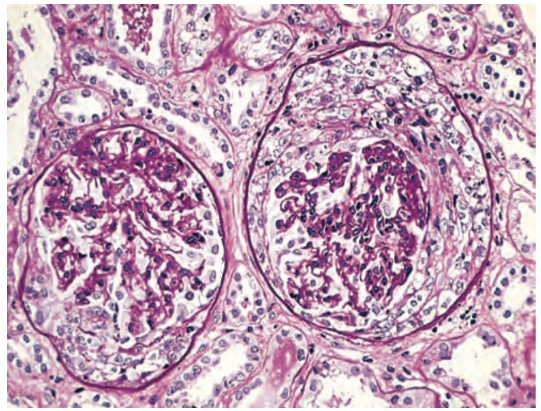


Adult
Hematuria 3d after pharyngitis
Recurrent gross hematuria
C3 normal





Rapid progressive



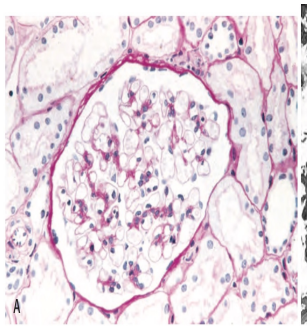
Linear:
Granular:
Pauci-immune:

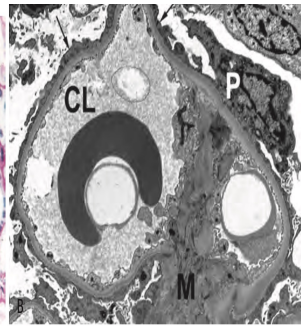
Sparsentan: ARB + Endothelin -

Nephrotic Syndrome

Proteinuria >3.5g/d, Edema, frothy urine

Child
Prior URTI
NSAIDS, Hodgkin's lymphoma
Urine loss of:

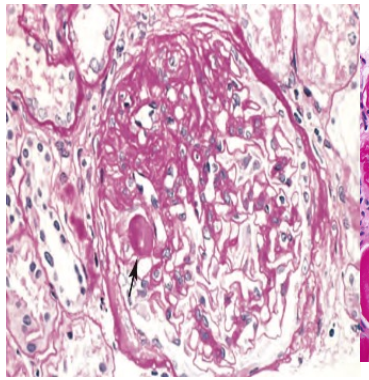


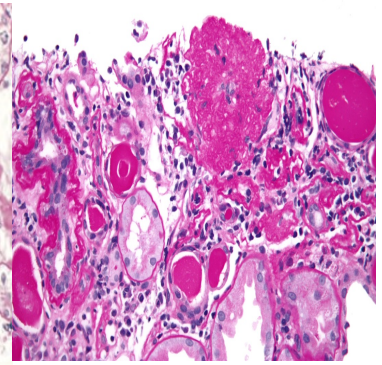


TOC:
SRNS:
DOC:
Steroid dependent NS:

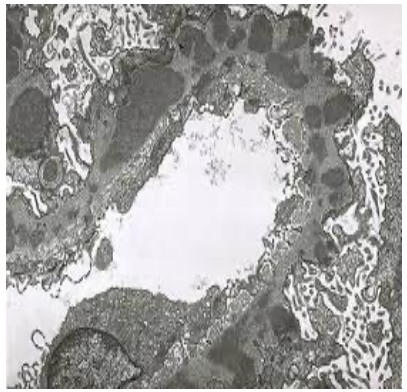
MMF/ Cyclophosphamide/ Levamisole
FRNS:

Adults
Heroin
HIVAN:APOL1 polymorphism
Reflux nephropathy
Obesity
Sickle cell anemia
NPHS2: Podocin-AR FSGS
Actinin 4: AD FSGS
TRPC6: Adult FSGS

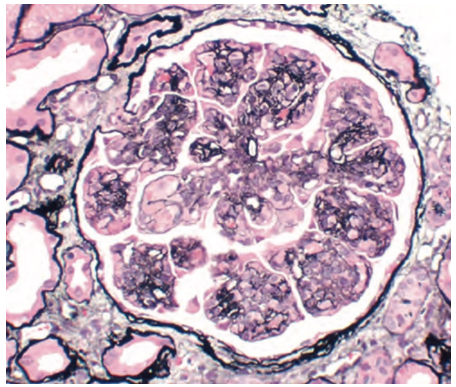


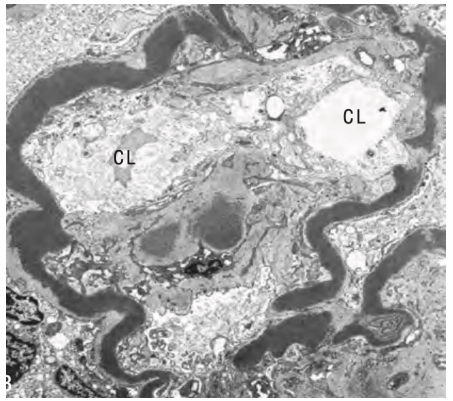


MC in elderly
Adenoca / melanoma
NSAID, penicillamine, gold
Hep B/
PLAR2
Thrombospondin, CD10



Adult
HCV /malaria
Cryoglobulinemia

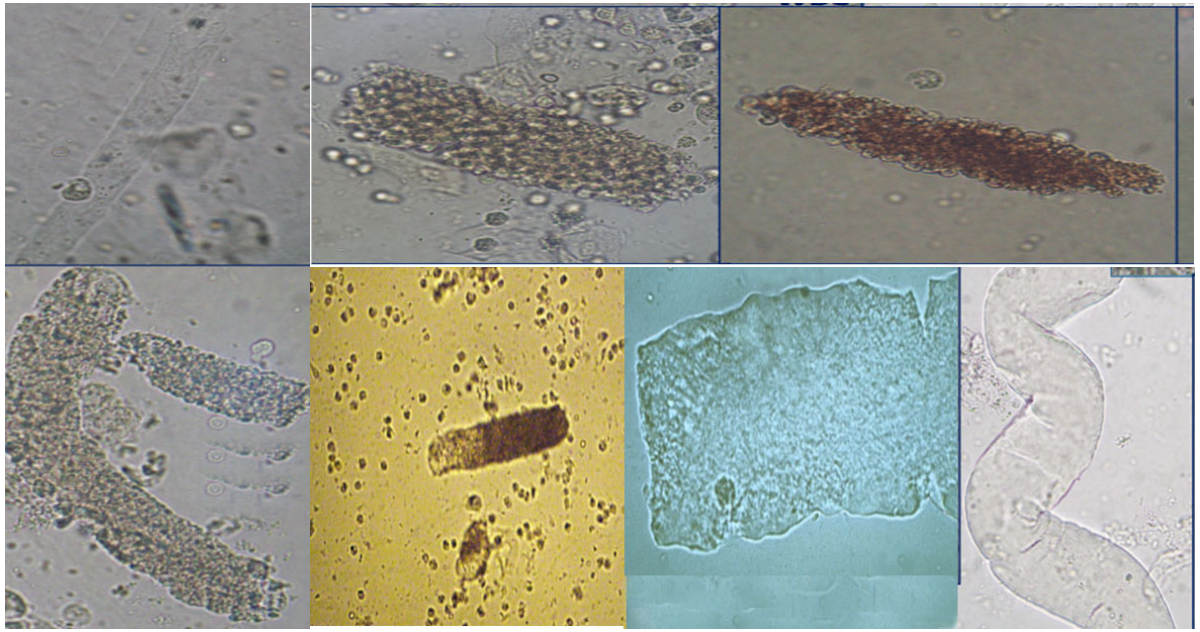




Nephrin NPHS1-Finnish type: Congenital NS

AKI vs CKD

	AKI	CKD
CMD		
Size		
Urine Osmolarity		
Anemia		
MBD		
Casts		



Biomarkers of AKI:
Cystatin C
KIM-1
NGAL
TIMP2
NABG

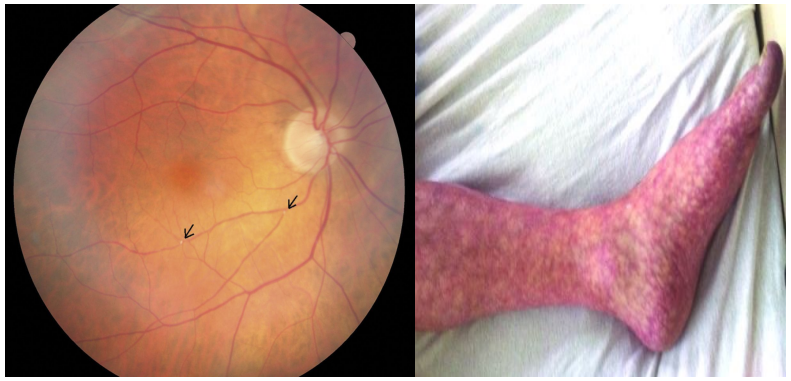
Renal papillary necrosis:
- NSAIDS
- Sickle cell disease or trait
- Acute pyelonephritis
- Infections
- Diabetes mellitus

Hematuria:
Glomerular:

Non-Glomerular:

AKI

-	Pre renal	Acute Tubular necrosis
Cause	Hypovolemia, CHF, NSAID / ACE-	Sepsis, Ischemia, Nephrotoxins: Rhabdomyolysis, IVH, Tumor lysis, MM, Drugs, Iodinated contrast
FeNa		
Urine Na		
Urine Osmolality		
BUN/Creatinine		
Urine casts		



Eosinophilia + Low complement

Fever + Rash + Eosinophilia + Drugs

Vancomycin, Aminoglycosides, Tenofovir, Cisplatin,Cidofovir, Foscarnet, AmpB, Crystals: Acyclovir, Indinavir

Acute Kidney Injury – Phases
Initiation (damage)
Maintenance (oligo/anuric)
Resolution: polyuria → risk of

Risk KDIGO Stage 1	EGFR Decrease by 25%/ Creatinine Increase by 1.5x	UO <0.5 mL/kg/hour for 6 hours
Injury KDIGO Stage 2	EGFR Decrease by 50%/ Creatinine Increase by 2x	UO <0.5 mL/kg/hour for 12 hours
Failure KDIGO Stage 3	EGFR Decrease by 75% Creatinine Increase by 3x	UO <0.3 mL/kg/hour for 24 hours or anuric for 12 hour
Loss	Persistent renal failure > 4 weeks	-
End stage	Persistent renal failure >3 months	-

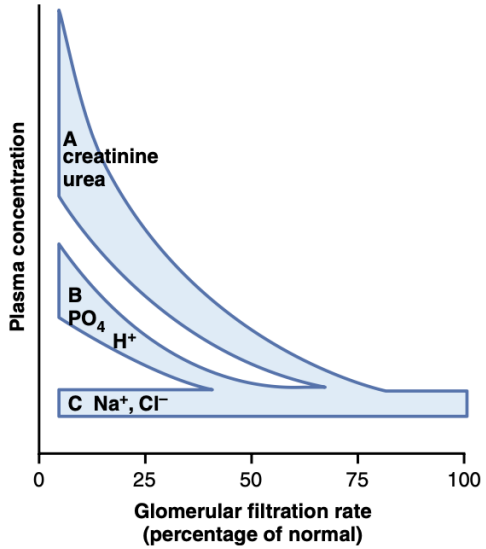
CKD

MCC of CKD:
MCC of death:
Anemia:
Indication:Hb <10 g/dl
Target:
Bone disease:
Rx:

Calciphylaxis:
Acid-base:
Uremia:
Pericarditis
P.Edema
pH <7.2
Potassium >6.5
Encephalopathy
Bleeding:

Dialysis disequilibrium syndrome DOC:

Stage of CKD	eGFR
Stage 1	≥ 90
Stage 2	60–89
Stage 3a	45–59
Stage 3b	30–44
Stage 4	15–29
Stage 5	<15



Acid-Base Balance

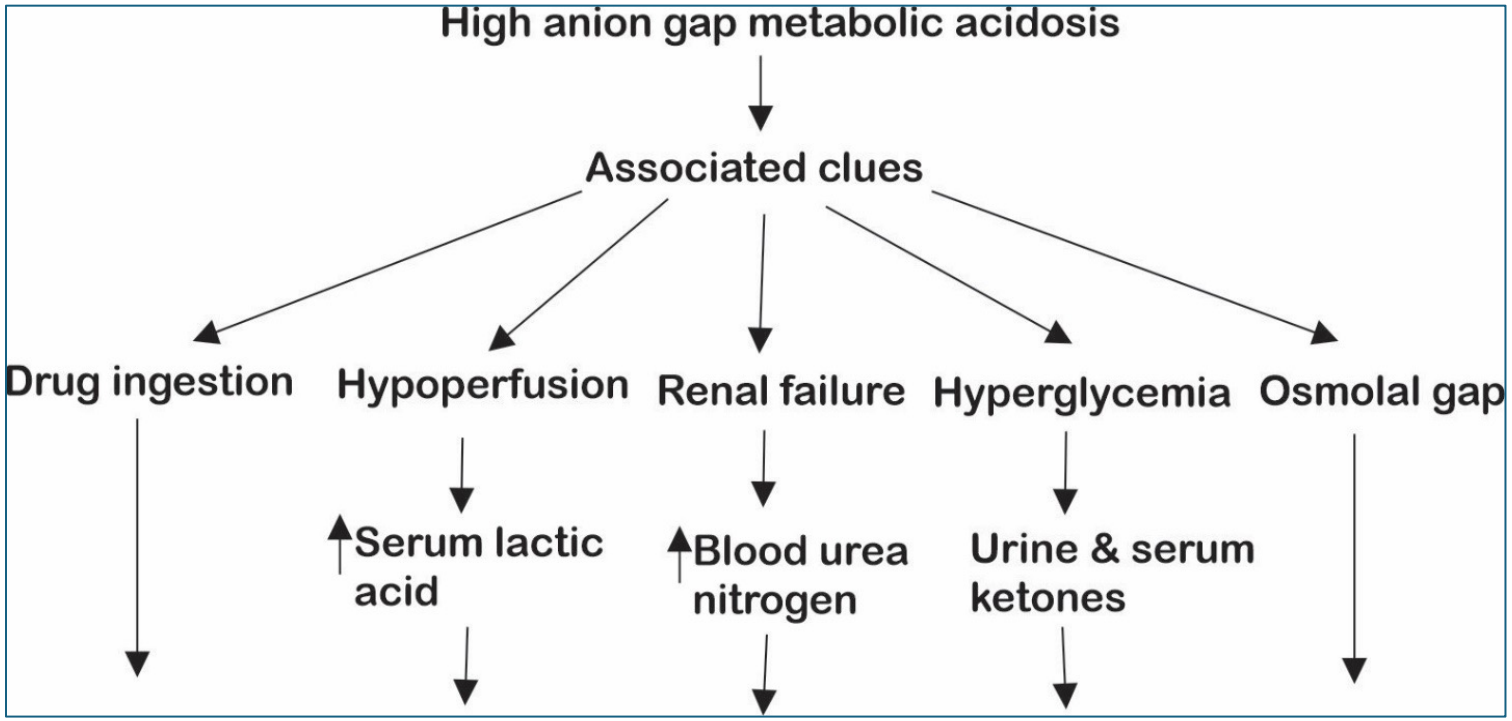
pH
CO_2
HCO_3^-
Derived value in ABG:

	Causes	pH	Primary Change	Compensation
METABOLIC ACIDOSIS	HAGMA NAGMA			
METABOLIC ALKALOSIS	Hyperaldosteronism, Vomiting, Loop/thiazides Bartter-Gittleman			
RESPIRATORY ACIDOSIS	Hypoventilation Airway obstruction			
RESPIRATORY ALKALOSIS	Hyperventilation			

$P_{CO_2} = 1.5[HCO3] + 8 \pm 2$

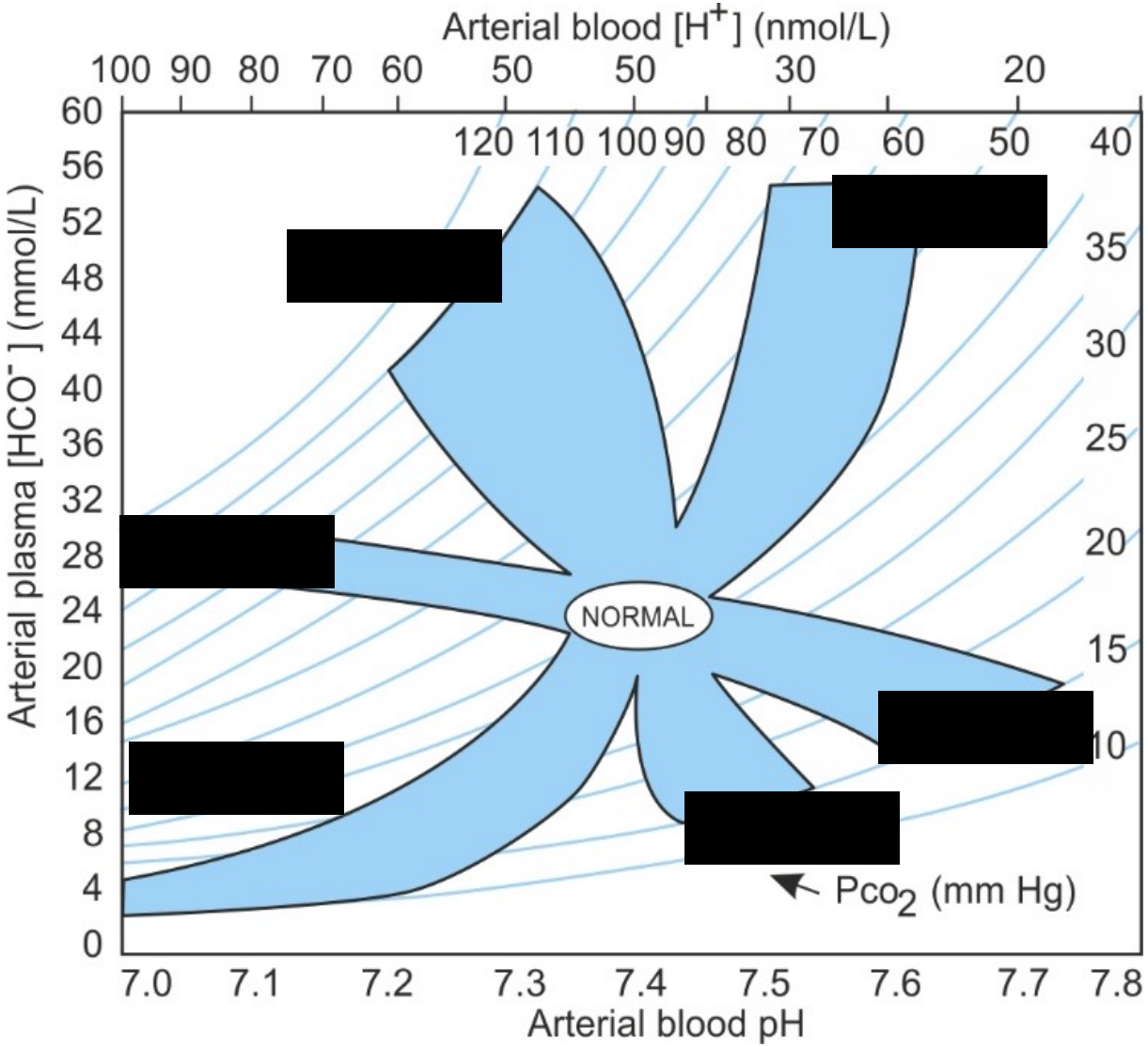
Metabolic Acidosis

Anion gap= (Na) - (HCO3 + Cl)
Normal: 8-12



NAGMA= Hyperchloremic acidosis:

- Renal tubular acidosis
- Diarrhea
- Addison disease/Spironolactone
- Carbonic anhydrase inhibitors
- Hyperalimentation
- Saline infusion
- Ureteral diversion (e.g., ileal loop)


Arterial blood [H+] (nmol/L)
100 90 80 70 60 50 50 30 20
120 110 100 90 80 70 60 50 40
Arterial plasma [HCO-] (mmol/L)
60 56 52 48 44 40 36 32 28 24 20 16 12 8 4 0
35 30 25 20 15 10
NORMAL
Pco2 (mm Hg)
7.0 7.1 7.2 7.3 7.4 7.5 7.6 7.7 7.8
Arterial blood pH

On laboratory investigations in a patient, pH=7.3, pCO_2=35 mm Hg, What is the likely acid base imbalance?

A. Respiratory acidosis

B. Metabolic acidosis

C. Metabolic alkalosis

D. Respiratory alkalosis

A patient is having pH-7.12, HCO_3-28 and PCO_2-50 mm Hg. What is the acid base disorder in this patient?

A. Metabolic acidosis with respiratory compensation

B. Metabolic alkalosis with respiratory compensation

C. Respiratory acidosis with renal compensation

D. Respiratory alkalosis with renal compensation

A patient is having pH-7.27, HCO_3-14 and PCO_2-28 mm Hg. What is the acid base disorder in this patient?

A. Metabolic acidosis with respiratory compensation

B. Metabolic acidosis with respiratory acidosis

C. Metabolic acidosis with respiratory alkalosis

D. Respiratory alkalosis with renal compensation

A patient who is a known case of CKD has complaints of vomiting. His ABG reports are as follows: pH-7.40, pCO_2- 40, HCO_3-25. Na-145, chloride-100. What is the metabolic abnormality?

A. Normal anion gap metabolic acidosis

B. High anion gap metabolic acidosis

C. No acid base abnormality

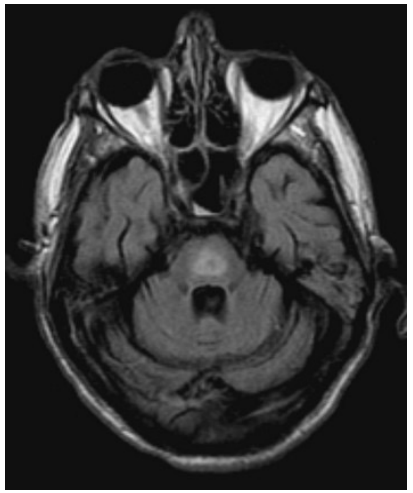
D. High anion gap metabolic acidosis with metabolic alkalosis

Electrolyte abnormalities

Serum osmolarity: 2(Na) + glucose/18 + BUN/2.8

MANAGEMENT of HypoNa
Sodium deficit:

Max: 8 meq/l in a day
Severe-Seizures/coma:
Overcorrection:



Free water deficit:

Drugs causing HyperK
K sparing diuretics
ACE-/ARB
Digoxin
β-blocker
Calcineurin inhibitors
Pentamidine
NSAIDs
Heparin
Succinylcholine
Trimethoprim

Management of Hyperkalemia:
1st step:

Transcellular spread:

Eliminate:
Most effective:
Binders:
- Sodium polystyrene sulfonate (SPS / Kayexalate)
- Patiromer
- Sodium zirconium cyclosilicate