Omurgalılarda Boşaltım

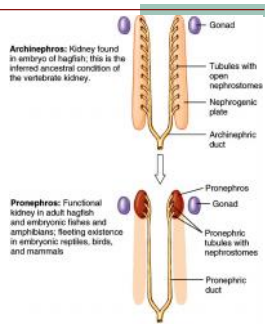
Doç. Dr. Hasan KOÇ

Omurgalılarda boşaltım

- Omurgalılarda boşaltım organı böbreklerdir. Üç tip böbrek vardır.
  - Pronefroz tip böbrekler
  - Mezonefroz tip böbrekler
- Bu boşaltım organları segmental olarak sıralanmış mezoderm orjinli kanalcıklardan ibarettir.
- Kirpikli birer huni (Nefrostom) aracılığıyla karın boşluğuyla (sölom) ilişkili olan bu kanalcıkların diğer uçları "Wolf kanalı" adı verlen bir boruya açılır.
- Aorttan segmental olarak ayrılan küçük damarların uçlarında meydana gelen kapiller yumaklar (Glomerulus) boşaltım kanallarının kirpikli huni kısmı ile ilişkilidir.

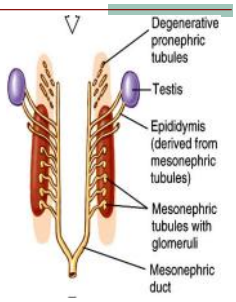
Pronefroz tip böbrek

- Balık ve Kurbağaların yalnız embriyo safhasında görülür.
- Glomeruluslar karın boşluğu içinde ve kirpikli hunilerin karşısında sıralanır.
- Böbreğin temel boşaltım birimi olan nefron, kirpikli huni ve bununla bağlantılı tüpçüklerden oluşur.

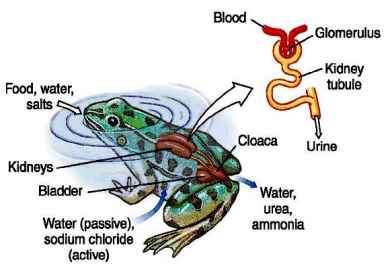


Mezonefroz böbrek

- Balık ve kurbağaların erginlerinde, sürüngen, kuş ve memelilerin de embriyolarında görülür.
- Glomeruluslar boşaltım kanallarının yan taraflarında meydana gelen kapsüller (Bowman kapsülü) tarafından sarılır.
- Bu tip böbreklerin bazıları kirpikli hunilerini kaybettiklerinden doğrudan doğruya Bowman kapsülleriyle başlar.
- Bu tip böbreklerde; pronefrozda olduğu gibi ya sadece kirpikli huni ve bununla bağlantılı tüpçükler veya bowman kapsülü oluşumu ile glomerulus + bowman kapsülü + tüpçük kısmından meydana gelir.

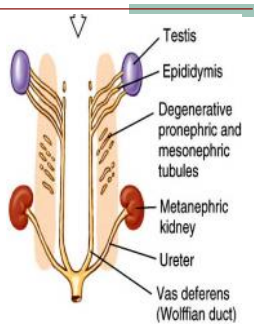


Mezonefroz böbrek

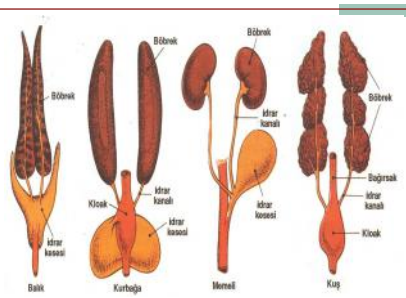


Metanefroz böbrek

- Sürüngen, kuş ve memelilerin erginlerinde görülür.
- Boşaltım tüpçükleri segmental sıralanmaz, fakat sayıları oldukça fazladır.
- Tüpçüklerde toplanan boşaltım maddelerini dışarı çıkarmak üzere üreter adı verilen bir boru oluşur.
- Boşaltım tüpçükleri üzerinde kirpikli huni yoktur.
- Bunların uçlarında bowman kapsülü bulunur.

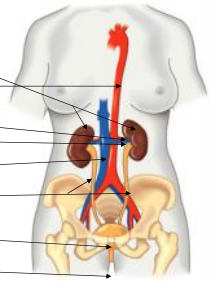


Omurgalılarda görülen böbrekler



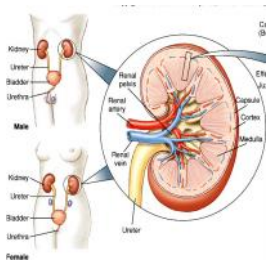
İnsanda boşaltım sistemi

- Böbrek (1 çift)
- Damarlar
  - Arteria abdominalis
    - Arteria renalis
    - Vena renalis
  - Inferior vena subclava
- Üreter (1 çift)
- Mesane (1 tane)
- Üretra (1 tane)



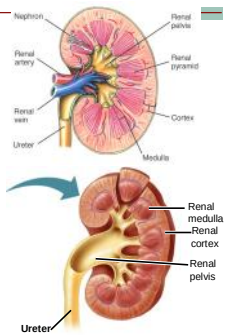
Memeli böbreğinin morfolojik yapısı

- Karın boşluğunun üst arka tarafında, fasulyeye benzer,
  - 10–11 cm boyunda,
  - 5–7 cm eninde,
  - Koyu kahverengi
- Her birinin ağırlığı ortalama 150 g kadardır.
- Erkek böbreği kadın böbreğine göre daha uzundur.
- Her iki böbreğin üst uçlarında piramid şeklinde birer böbreküstü bez bulunur.



Memeli böbreğinin anatomik yapısı

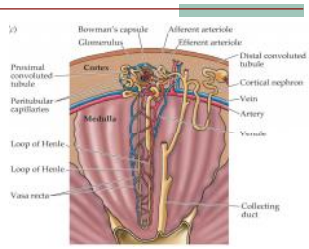
- Her böbrek ince bir zarla sarılmıştır.
- İki katmanı vardır:
  - 1. Kabuk (cortex);
  - 2. Öz (medulla).
- Kabuk kırmızımsı-kahverengi, medulla daha koyudur.
- Böbreğin ortasına doğru uzantılar içerir. Bunlara piramid denir.
- Her böbrekte yaklaşık 12–14 piramid bulunur ki bunların uçlarına papilla adı verilir.



Nefron

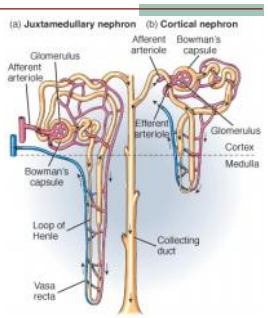
- Böbreğin yapısal ve işlevsel en küçük birimine nefron adı verilir.
- Her bir böbrekte 1–4 milyon kadar nefron vardır.
- Nefron aşağıdaki kısımlardan oluşur.
  - Malpighi cisimciği
    - Bowman kapsülü
    - Glomerulusdan
    - Afferent arteriyol
    - Efferent arteriyol
  - Borular kısmı
    - Proksimal kıvrık tüp
    - Henle kulpu
    - Distal kıvrık tüp
    - Toplayıcı kanal

} İnsanda ve 5 cm

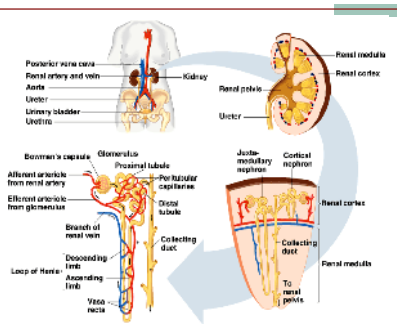


Nefron tipleri

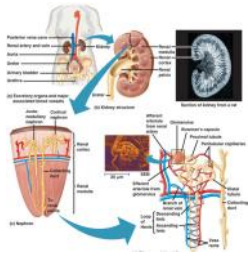
- Kortikal nefron
  - Bütün nefronların % 80'i
  - Glomeruli in the outer cortex
  - Descending limb of the loop of Henle enters partially into the medulla
  - No vasa recta
- Jukstamedullary nefron
  - Bütün nefronların % 20'si
  - Glomeruli lie in the inner cortex
  - Descending limb enters entire length of medulla
  - Abundant in desert species
  - Vasa recta present



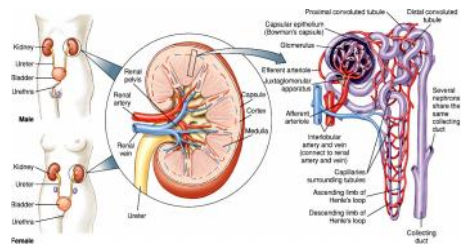
İnsan boşaltım sisteminin anatomik yapısı



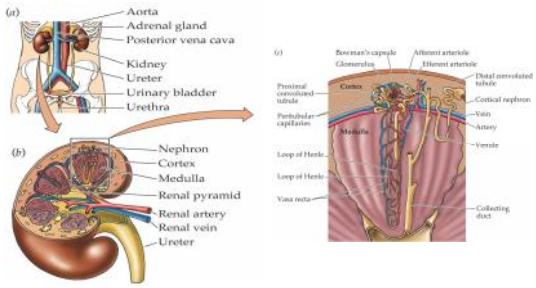
İnsan boşaltım sisteminin anatomik yapısı



İnsan boşaltım sisteminin anatomik yapısı

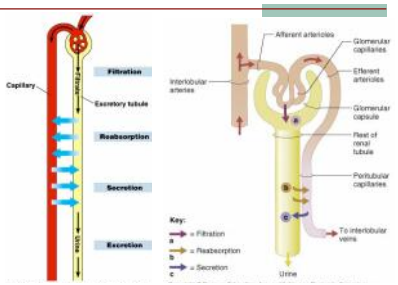


İnsan boşaltım sisteminin anatomik yapısı



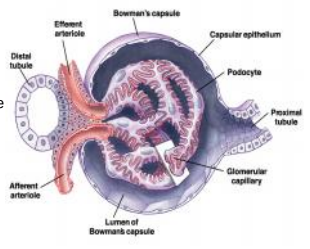
Boşaltımın aşamaları – idrar oluşum aşamaları

- **Filtrasyon**
- **Reabsorpsiyon**
- **Sekresyon**
- **Ekskresyon**

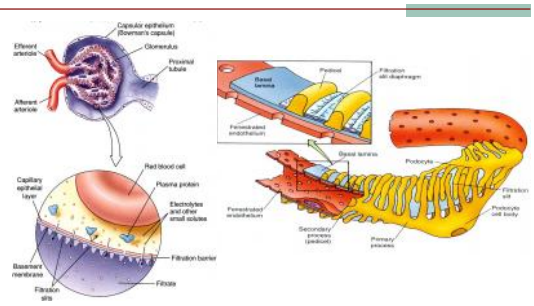


Glomerulus

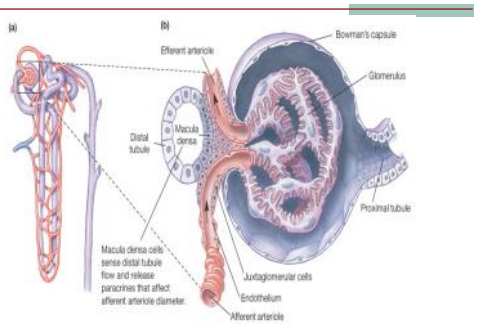
- Glomerular capillary membrane
  - Three major layers:
    1) Endothelium
    2) Basement membrane
    3) Podocytes (epithelial cells)



Glomerular capillary membrane

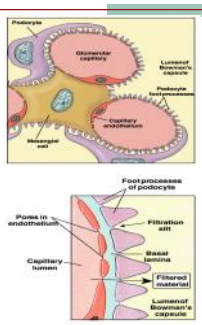


Glomerulus

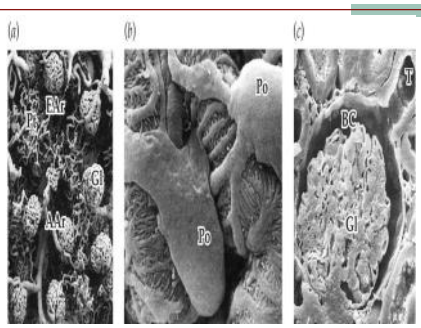


Podositler

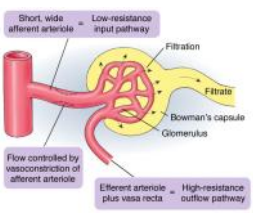
- Surround outer surface of the capillary membrane; cell body with several 'arms' or pedicels (foot processes)
- Narrow slits between pedicels allow for the passage of molecules based on MW and charge
- Glomerular capillaries are fenestrated, allowing for a high filtration rate
- Most substances except large proteins are filtered



Podositlerin yapısı

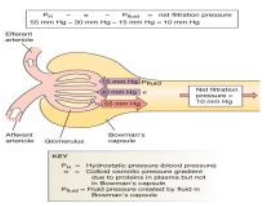


Filtrasyon



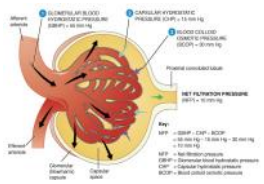
Glomerular Filtrasyon

1) P_G: glomerular hydrostatic pressure; promotes filtration (60 mm Hg)
2) P_B: hydrostatic pressure in Bowman's capsule; opposes filtration (18 mm Hg)
3) π_G: colloidal osmotic pressure of the glomerular capillary; opposes filtration (32 mm Hg)
4) π_B: colloid osmotic pressure of the Bowman's capsule; promotes filtration (0 mm Hg)

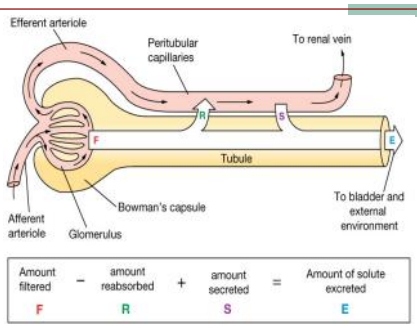


Glomerular Filtrasyon

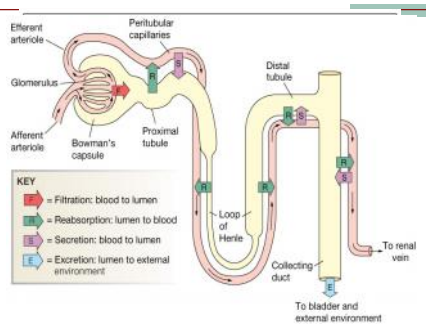
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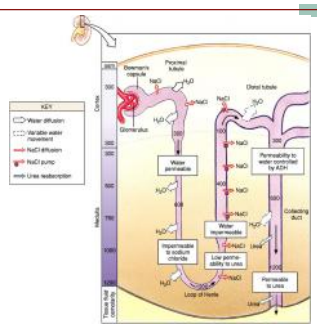
Filtrasyon



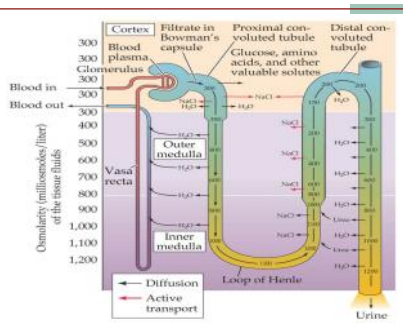
Filtrasyon



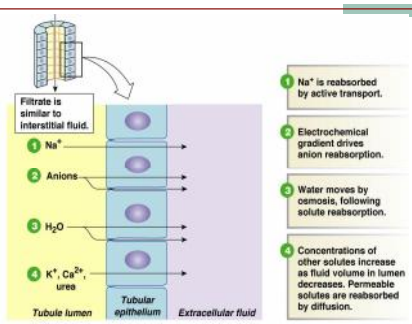
Tubüler reabsorpsiyon



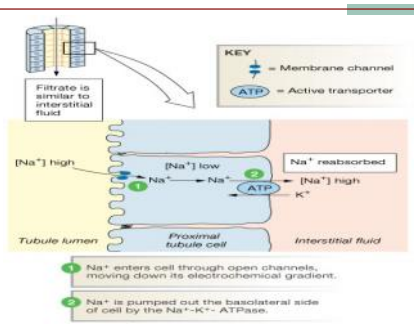
Tubüler reabsorpsiyon



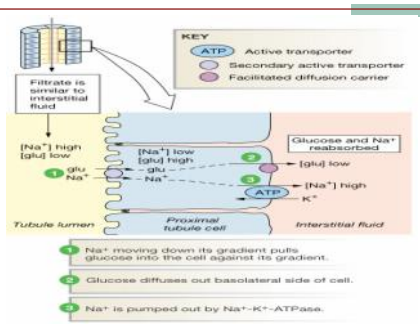
General Mechanisms of Tubular Reabsorption



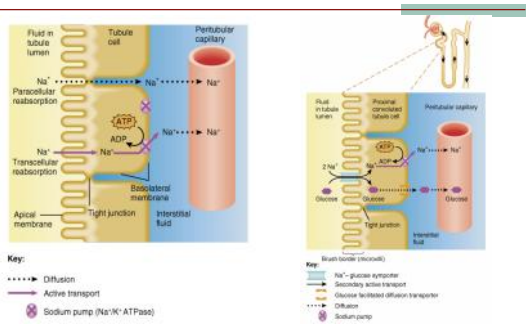
Tubular Reabsorption: Primer Active Transport



Reabsorption: Secondary Active Transport

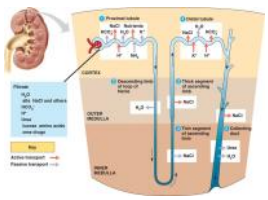


Tubüler reabsorpsiyon



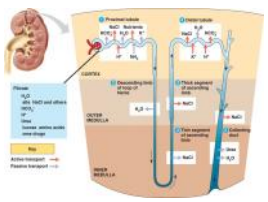
Proksimal kıvrık tüp

- Reabsorbsiyon
  - water, NaCl, amino acid, glucose, K+
  - bicarbonate (HCO3; to maintain pH)
- Secretion
  - ammonia, H+ (pH)
  - drugs and other poisons
- Substantially alter the volume and composition of filtrate



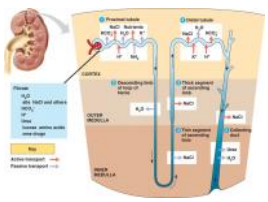
Henle kulpu

- İnen kol
  - Reabsorb
    - water
- Çıkan kol
  - Reabsorb
    - NaCl (by passive transport in *thin* segment)
    - NaCl (by active transport in *thick* segment)



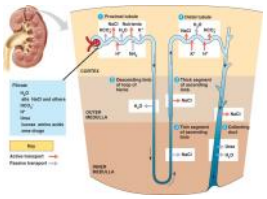
Distal kıvrık tüp

- Reabsorpsiyon
  - NaCl
  - bikarbonat (HCO3; pH)
- Secresyon
  - H+ (pH)
  - K+

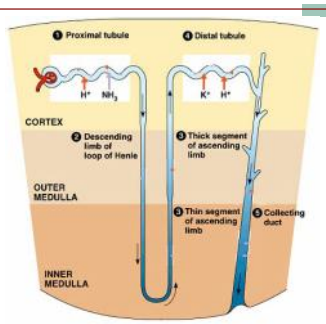


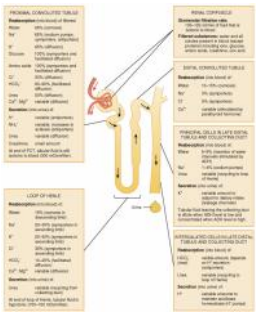
Toplayıcı kanal

- Reabsorbsiyon
  - Su,
  - NaCl,
  - Üre



Tubüler sekresyon





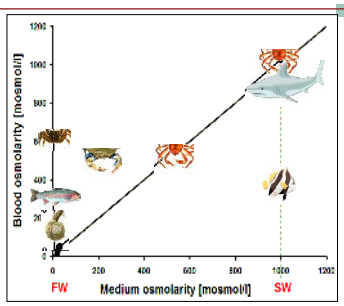
Strategies and mechanisms of osmotic regulation

Strategies and mechanisms of osmotic regulation

- ✓ **Reduction of the osmotic gradient to reduce passive fluxes**
- **Cell volume regulation to adjust to varying internal osmolarities**
- **Reduction of body surface permeability to reduce passive fluxes**
- **Urine production to compensate for passive influx of water**
- **Active NaCl transport to compensate for passive loss or influx of salt**



Osmotic concentrations and gradients in aquatic animals



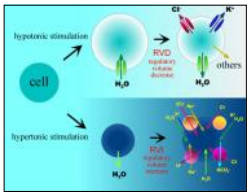
Strategies and mechanisms of osmotic regulation

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- Urine production to compensate for passive influx of water
- Active NaCl transport to compensate for passive loss or influx of salt

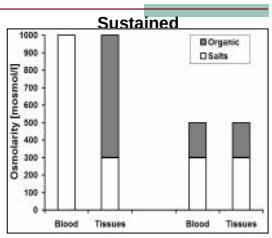


Cell volume regulation

Fast



Sustained



Volume adjustment by salt transport across the cell membrane

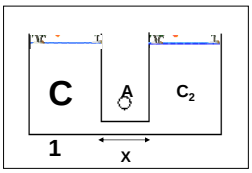
Volume adjustment by modification of cellular organic osmolytes (amino acids)

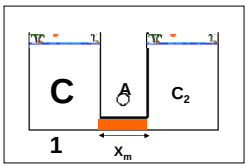
Strategies and mechanisms of osmotic regulation

- Reduction of the osmotic gradient to reduce passive fluxes
- Cell volume regulation to adjust to varying internal osmolarities
- ✓ Reduction of body surface permeability to reduce passive fluxes
- Urine production to compensate for passive influx of water
- Active NaCl transport to compensate for passive loss or influx of salt



What is permeability?





The diffusion coefficient D depends on temperature, the size of the difusing particles and the viscosity of the medium.

Permeability is quantifying the ability of a barrier to give passage to a diffusing substance. The barrier is permeable; the particle is permeant!

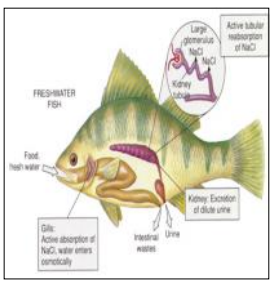
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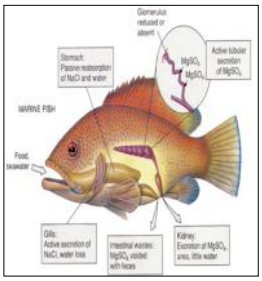
Two examples

- Freshwater fish suffer from a continuous passive influx of water driven by the osmotic gradient.
- The kidneys of freshwater fish produce a large volume of diluted urine to counterbalance the passive water inflow.
- Freshwater fish do hardly drink!



Two examples

- Seawater fish suffer from a continuous passive loss of water driven by the osmotic gradient.
- The kidneys of seawater fish produce a small volume of urine rich in urea and magnesium.
- Seawater fish drink seawater to counterbalance the passive loss of water!

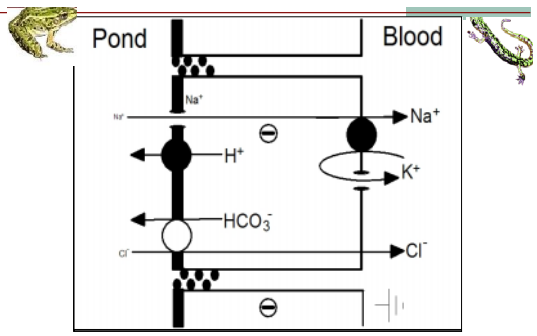


Strategies and mechanisms of osmotic regulation

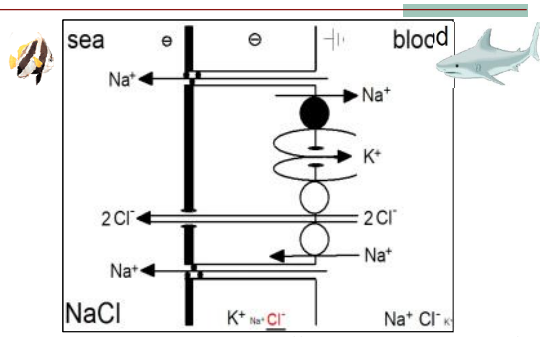
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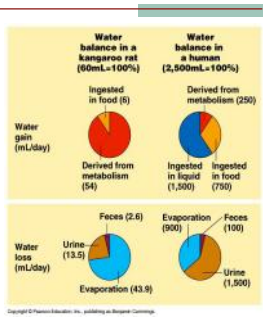
NaCl absorption in freshwater animals



NaCl secretion in marine fish







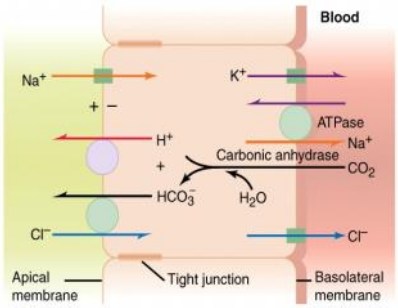
Adaptasyonlar

Cool Adaptations

- Mollusks
  - kidney organ that also aid in gamete secretion
- Crustaceans - antennal or green glands
  - also use gills and areas of the body where the cuticle is thin
- Amphibians
  - first terrestrial organisms
  - kidney like freshwater fishes - stay in wet places on land
  - some larval forms have a nephrostome
  - some live in freshwater - like fishes
  - If water is in short supply - excrete N as urea
  - skin also
  - some anurans (frogs) live in low water - retain large amount of urea
  - dessert - excrete N as uric acid
    - or may store water in lymph sacs - up to 2 years



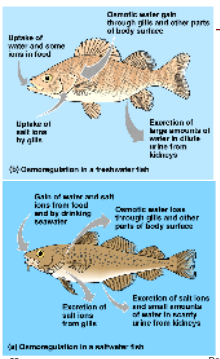
Gill epithelium of a freshwater fish or frog skin

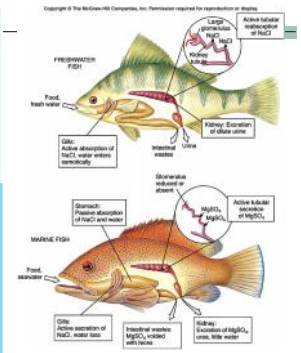


Cool Adaptations

- African lungfish
- normal in rivers and streams as it swims
- during drought it estivates converts ammonia to urea
- rain returns and takes up water and then secretes urea







Cool Adaptations

Reptiles

- Often found in dry places freshwater
- like freshwater fishes marine - use salt gland to get rid of extra salts terrestrial
- reabsorb much water from kidneyurine never more concentratedentrated than blood plasma
- or else lose water from blood
- ammonia → less toxic urea or uric acid

- uric acid leaves via cloaca as whitish paste like
- skin reduces water loss
- glomeruli and reduced tubular filtration - low water loss



Cool Adaptations

- Birds and Mammals
  - beaver has short loops - urine 2x's as concentrated as blood
  - desert rodents - urine 25x's as concentrated as blood
    - remove more water than reptiles or amphibians
  - camel 8x's more concentrated than plasma
  - mouse 22'x more concentrated than plasma



II.Osmoregulation in aquatic environments

- **Migrating fish (e.g. salmonids, eels)**
  - Freshwater to seawater
    - Proton-pump is down-regulated (reduces Na^+ uptake)
    - Increase in Na^+ influx stimulates secretion of growth hormone and cortisol
    - **Cortisol** and **growth hormone** cause proliferation of chloride cells and increase in the infolding of the basolateral membrane
    - Increase in Na^+-K^+ ATPase activity (increases secretion of NaCl)
    - Plasma Na^+ levels return to normal

II.Osmoregulation in aquatic environments

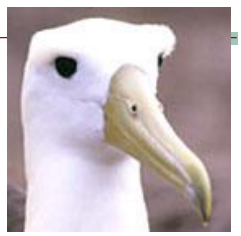
- Seawater to freshwater
  - Paracellular gaps between the chloride cells and accessory cells close (reduces Na^+ secretion)
  - Plasma **prolactin** levels increase and cause the number of chloride cells to decrease and apical pits to disappear
  - Decrease in Na^+-K^+ ATPase activity
  - Up-regulation of the proton pump

II.Osmoregulation in aquatic environments

- **Marine birds and reptiles**
  - Salt glands
    - Unable to produce a hyperosmotic urine
    - Drink seawater to obtain water
    - Integument has low permeability to Na^+
    - Salt gland located above the orbit of the eye in some sea birds and in iguanas and empty into the nasal cavity; in sea snakes (mouth); in estuarine crocodiles (tongue)



timsah



deniz kuşu



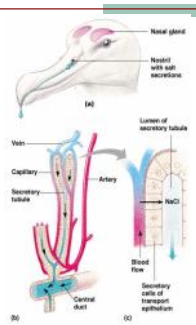
marine iguana

II.Osmoregulation in aquatic environments

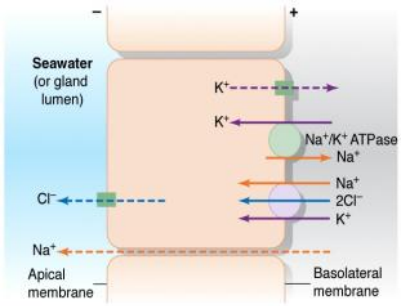
- **Avian salt gland**
  - Operates in the same fashion as a chloride cell
  - Flow of blood through capillaries is in the opposite direction to the flow of secretory fluid (countercurrent system)
  - Countercurrent system minimizes concentration gradient of Na^+ from the blood to the tubular lumen
  - Salt gland is activated in response to increased salt uptake or an increase in ECF volume

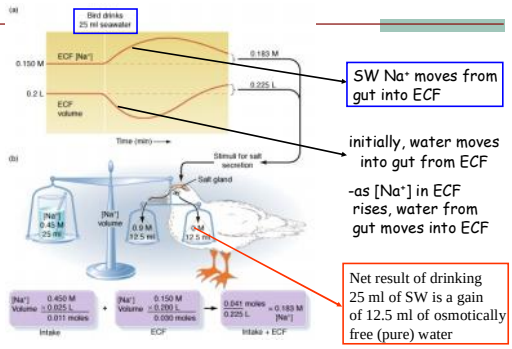
Cool Adaptations





Chloride cell, salt gland or rectal gland



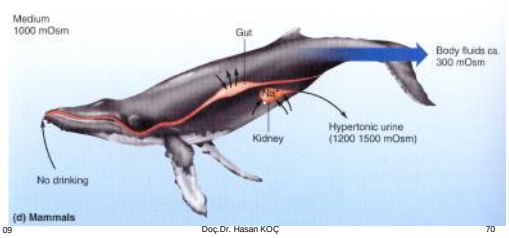


II.Osmoregulation in aquatic environments

- **Marine mammals**
  - Do not have salt glands and do not drink seawater
  - Obtain water from food and metabolism
  - Highly efficient kidneys produce a hypertonic urine
  - Nursing females produce milk with high fat but low water content
  - Some juvenile animals can use water derived from the oxidation of body fat
  - Modifications in nasal passages to reduce water loss
  - Ability to lower metabolic rate

Water-salt relations in a marine mammal

- obtain water from food and metabolism
- conserves water by producing a hypertonic urine



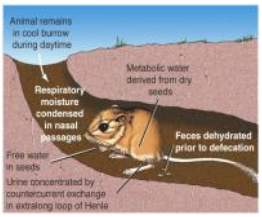
III. Osmoregulation in the terrestrial environment

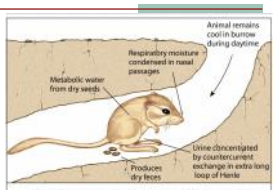
- **Osmoregulatory challenges on land**
  - Water and salts must be obtained from food
  - Animals are constantly losing water through respiration, evaporative cooling, urine and feces
  - Physiological and behavioral mechanisms used to retain water and ions
  - Some earthworms and terrestrial molluscs can cope with 40-80% water loss; insects (30-35%), mammals and birds (5-10%)

III. Osmoregulation in the terrestrial environment

- **Desert mammals**
  - Kangaroo rat is exposed to excessive heat and lack of water
  - Avoids daytime heat by remaining in burrow and forages at night
  - Excretes a highly concentrated urine
  - Rectal reabsorption of water from food
  - Receives water from diet and metabolism
  - Respiratory moisture condensed in nasal passages

Water conservation by the kangaroo rat





Water Balance in a Human and a Kangaroo Rat, a Desert Rodent

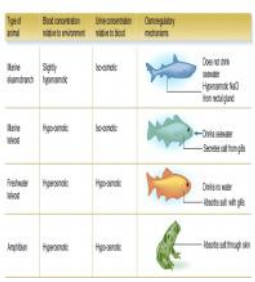
	Human (%)	Kangaroo Rat (%)
Gains		
Drinking	48	0
Free water in food	40	10
Metabolic water	12	90
Losses		
Urine	60	25
Evaporation (lungs and skin)	34	70
Feces	6	5

Environmental Adaptations

- marine bony fish
  - produce scanty amount of urine
  - fewer glomeruli
  - excrete salts across gill membranes
- cartilaginous fish
  - ionic regulators
  - urea stored in tissue fluids
  - rectal gland
- amphibians
  - produce copious amount of urine
  - those living in arid regions have skin less permeable to water
- reptiles
  - uric acid excretion conserves water
  - scaly skin
  - shelled egg
- birds
  - may produce urine more concentrated than tissue fluid
  - same adaptations as reptiles

Group	Blood osmolarity	Osmotic gradient	Cell volume	Body surface permeability	Urine volume	Active transport	Example
Marine Osmoconformer	1000	no	no need	high	low	yes divalent cations	
Terrestrial from the sea	600-1000	water	yes	high	no/low	yes NaCl absorption	
Euryhaline Osmoconformer	500-1000	no	yes	high	low	yes Cell volume regulation	
Brackish water Hyperregulator	400-600	150-250	yes	reduced	high	yes NaCl absorption	
Freshwater Hyperregulator	50-500	40-490	yes	low to very low	low	yes NaCl absorption	
Terrestrial from freshwater	50-400	water	yes	low to high	low	yes absorption of salt and water from urine	
Marine Hyporegulator	300-400	600-700	yes	low to very low	low	yes NaCl secretion	
Marine Hyposaline	1000	0	yes	low to very low	low	yes NaCl secretion	

Seawater ~ 1000 mosmol/l, freshwater ~ 20 mosm o/l





Omurgalı böbreğinin adaptasyonları

Memeliler

- Terrestial: depend on juxtamedullary nephron and long Loop of Henle
- Aquatic: short Loop of Henle



Kuşlar

- Juxtamedullary nephron, with shorter Loop of Henle





Sürüngenler

- Cortical nephron
- Epithelium of cloaca help conserving water by reabsorbing from urine and feces.



Amfibiler

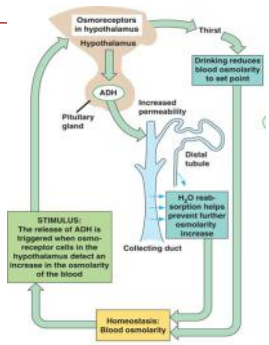
- Produce large amount of diluted urine
- Aquatic: use skin to reabsorb salt
- Terrestial: use urinary bladder to reabsorb water



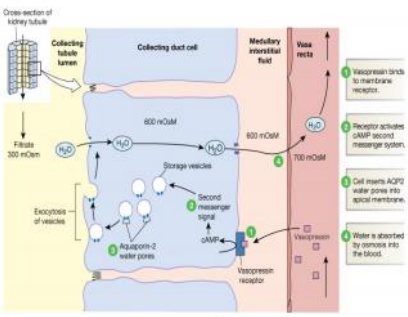
Osmoregülasyonun düzenlenmesi

Nervous system and hormones regulate kidney functions

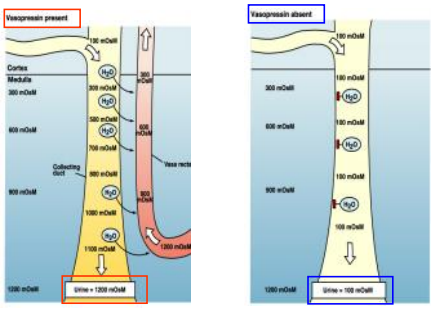
- Antidiuretic hormone (ADH)
  - Produced in hypothalamus, stored and released from anterior pituitary gland.
  - When osmolarity of blood rises, production and release of ADH increases
  - ADH targets distal tubules and collecing ducts.
  - Increases water reabsorption in the distal tubules and collecting ducts of the kidney.
  - Stimulated by a rise in the blood's osmolarity (>300 mosm/L)
  - Enhances fluid retention by making the kidneys reclaim more water.



Formation of Water Pores: Mechanism of Vasopressin Action

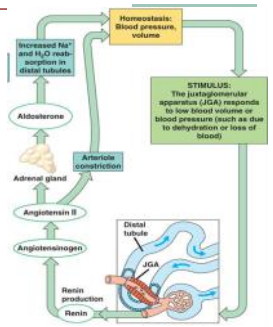


Water reabsorption in the presence and absence of ADH

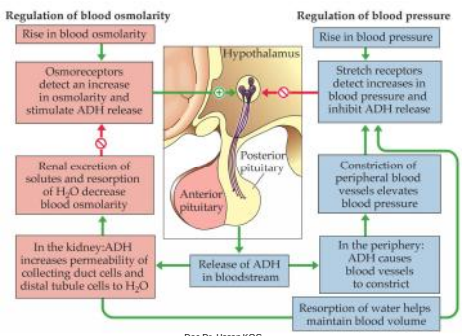


Nervous system and hormones regulate kidney functions

- The renin-angiotensin-aldosterone system (RAAS)
  - Responds to a loss of salt and water in the blood
  - Stimulated by low blood volume or pressure
  - Increases water and sodium ion reabsorption in the proximal and distal tubules
  - Leads to an increase in blood volume and pressure
  - Opposed by the hormone atrial natriuretic factor (ANF)
    - Released by atria
    - Inhibits release of renin

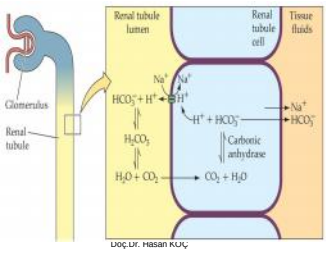


Control and Regulation

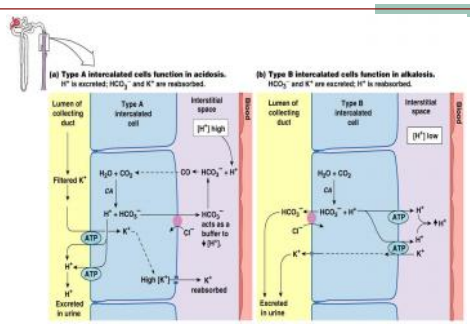


Asit baz dengesi

- bicarbonate buffer system
  - kidneys actively control H^+ and HCO^-_3 content in blood



Asit baz dengesi



Vücut su dengesi

