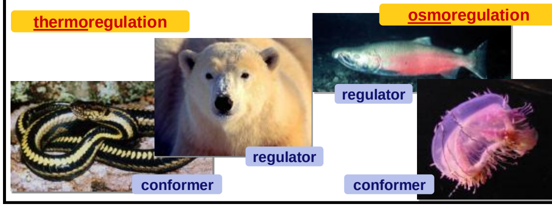
Regulating the Internal Environment

Conformers vs. Regulators

- <u>Two</u> evolutionary paths for organisms
  - regulate internal environment
    - maintain relatively constant internal conditions
  - conform to external environment
    - allow internal conditions to fluctuate along with external changes



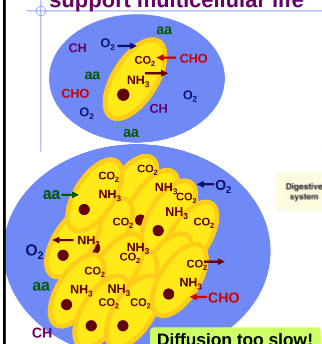
Homeostasis

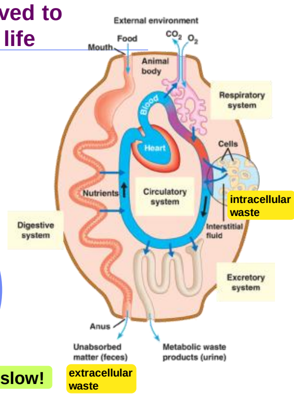
- Keeping the balance
  - animal body needs to coordinate many systems all at once
    - temperature
    - blood sugar levels
    - energy production
    - water balance & intracellular waste disposal
    - nutrients
    - ion balance
    - cell growth
  - maintaining a "steady state" condition

Regulating the Internal Environment

Water Balance & Nitrogenous Waste Removal

Animal systems evolved to support multicellular life

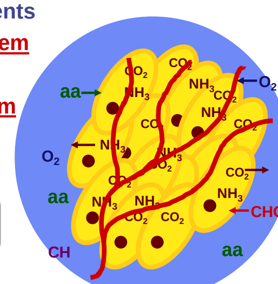




Overcoming limitations of diffusion

- Evolution of exchange systems for
  - distributing nutrients
    - circulatory system
  - removing wastes
    - excretory system

systems to support multicellular organisms

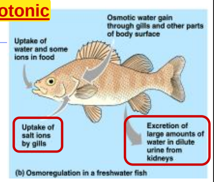


Osmoregulation

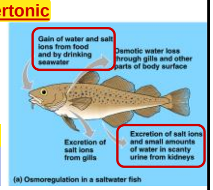
- Water balance
  - freshwater
    - hypotonic
    - water flow into cells & salt loss
  - saltwater
    - hypertonic
    - water loss from cells
  - land
    - dry environment
    - need to conserve water
    - may also need to conserve salt

Why do all land animals have to conserve water?
- always lose water (breathing & waste)
- may lose life while searching for water

hypotonic



hypertonic



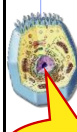
Intracellular Waste

Animals poison themselves from the inside by digesting proteins!

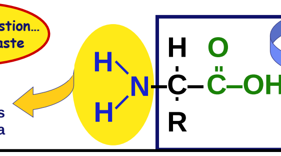
- What waste products?
  - what do we digest our food into…
    - carbohydrates = CHO → $CO_2 + H_2O$
    - lipids = CHO → $CO_2 + H_2O$
    - proteins = CHON → $CO_2 + H_2O$ + N
    - nucleic acids = CHOPN → $CO_2 + H_2O$ + P + N

lots!

very little



cellular digestion… cellular waste

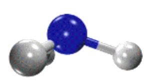


NH_2 becomes ammonia

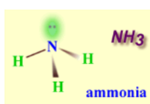
$CO_2 + H_2O$

Nitrogenous waste disposal

- Ammonia (NH_3)
  - very toxic
    - carcinogenic
  - very soluble
    - easily crosses membranes
  - must dilute it & get rid of it… *fast!*
- How you get rid of nitrogenous wastes depends on
  - who you are (evolutionary relationship)
  - where you live (habitat)

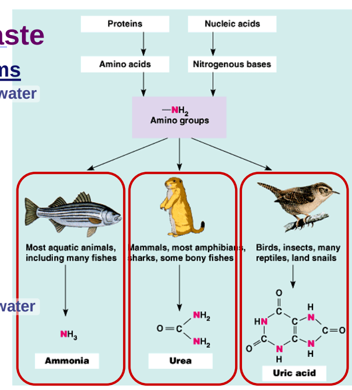


aquatic | terrestrial | terrestrial egg layer



Nitrogen waste

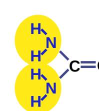
- Aquatic organisms
  - can afford to lose water
  - ammonia
    - most toxic
- Terrestrial
  - need to conserve water
  - urea
    - less toxic
- Terrestrial egg layers
  - need to conserve water
  - need to protect embryo in egg
  - uric acid
    - least toxic



Freshwater animals

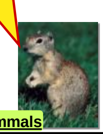
- Water removal & nitrogen waste disposal
  - remove surplus water
    - use surplus water to dilute ammonia & excrete it
      - need to excrete a lot of water so dilute ammonia & excrete it as very dilute urine
    - also diffuse ammonia continuously through gills or through any moist membrane
  - overcome loss of salts
    - reabsorb in kidneys or active transport across gills

Land animals



- Nitrogen waste disposal on land
  - need to conserve water
  - must process ammonia so less toxic
    - urea = larger molecule = less soluble = less toxic
      - $2NH_2 + CO_2$ = urea
      - produced in liver
  - kidney
    - filter solutes out of blood
    - reabsorb H_2O (+ any useful solutes)
    - excrete waste
      - urine = urea, salts, excess sugar & H_2O
        - urine is very concentrated
        - concentrated NH_3 would be too toxic

Urea costs energy to synthesize, but it's worth it!



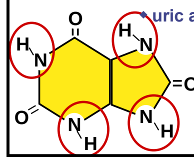
mammals

Egg-laying land animals

- Nitrogen waste disposal in egg
  - no place to get rid of waste in egg
  - need even less soluble molecule
    - uric acid = BIGGER = less soluble = less toxic
  - birds, reptiles, insects

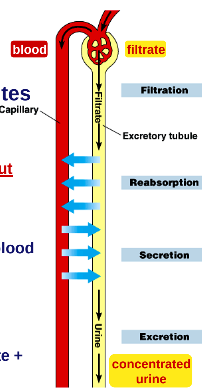
Uric acid

- Polymerized urea
  - large molecule
  - precipitates out of solution
    - doesn't harm embryo in egg
      - white dust in egg
    - adults still excrete N waste as white paste
      - no liquid waste
      - uric acid = white bird "poop"!

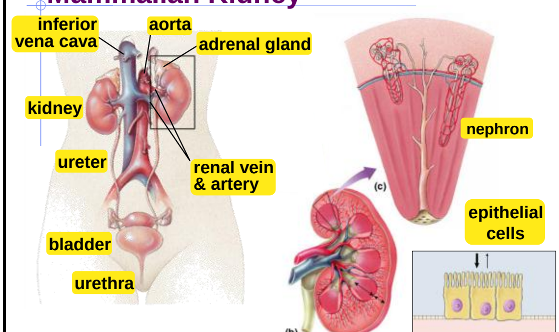


Mammalian System

- Filter solutes out of blood & reabsorb H_2O + desirable solutes
- Key functions
  - filtration
    - fluids (water & solutes) filtered out of blood
  - reabsorption
    - selectively reabsorb (diffusion) needed water + solutes back to blood
  - secretion
    - pump out any other unwanted solutes to urine
  - excretion
    - expel concentrated urine (N waste + solutes + toxins) from body

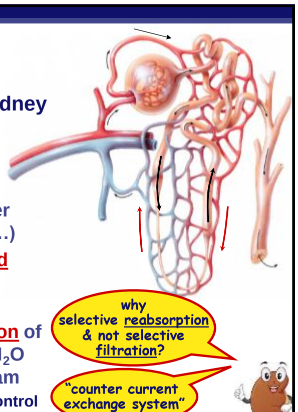


Mammalian Kidney



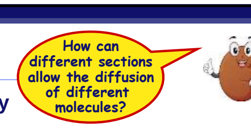
Nephron

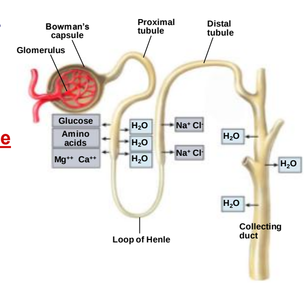
- Functional units of kidney
  - 1 million nephrons per kidney
- Function
  - filter out urea & other solutes (salt, sugar…)
  - blood plasma filtered into nephron
    - high pressure flow
  - selective reabsorption of valuable solutes & H_2O back into bloodstream
    - greater flexibility & control



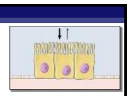
Mammalian kidney

- Interaction of circulatory & excretory systems
- Circulatory system
  - glomerulus = ball of capillaries
- Excretory system
  - nephron
  - Bowman's capsule
  - loop of Henle
    - proximal tubule
    - descending limb
    - ascending limb
    - distal tubule
  - collecting duct

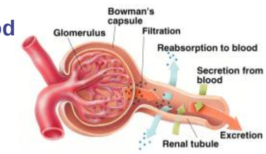




Nephron: Filtration



- At glomerulus
  - filtered out of blood
    - H_2O
    - glucose
    - salts / ions
    - urea
  - not filtered out
    - cells
    - proteins

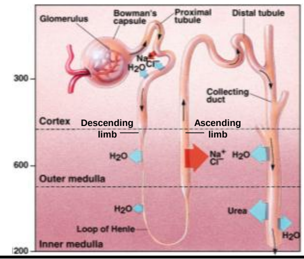


high blood pressure in kidneys
force to push (filter) H_2O & solutes out of blood vessel

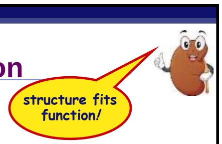
BIG problems when you start out with high blood pressure in system
hypertension = kidney damage

Nephron: Re-absorption

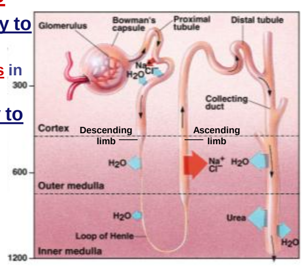
- Proximal tubule
  - reabsorbed back into blood
    - NaCl
      - active transport of Na^+
      - Cl^- follows by diffusion
    - H_2O
    - glucose
    - HCO_3^-
      - bicarbonate
      - buffer for blood pH



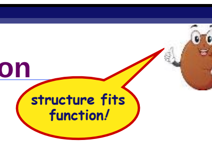
Nephron: Re-absorption



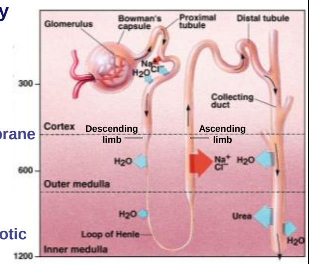
- Loop of Henle
  - descending limb
    - high permeability to H_2O
      - many aquaporins in cell membranes
    - low permeability to salt
      - few Na^+ or Cl^- channels
  - reabsorbed
    - H_2O



Nephron: Re-absorption

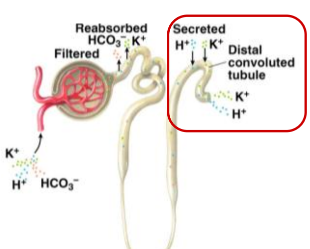


- Loop of Henle
  - ascending limb
    - low permeability to H_2O
    - Cl^- pump
    - Na^+ follows by diffusion
      - different membrane proteins
  - reabsorbed
    - salts
      - maintains osmotic gradient



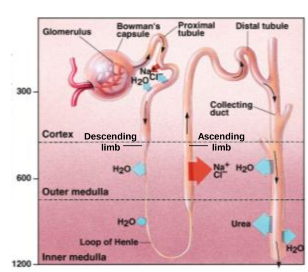
Nephron: Re-absorption

- Distal tubule
  - reabsorbed
    - salts
    - H_2O
    - HCO_3^-
      - bicarbonate



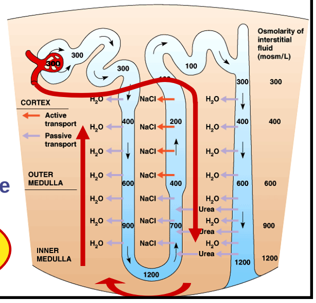
Nephron: Reabsorption & Excretion

- Collecting duct
  - reabsorbed
    - H_2O
  - excretion
    - concentrated urine passed to bladder
      - impermeable lining



Osmotic control in nephron

- How is all this re-absorption achieved?
  - tight osmotic control to reduce the energy cost of excretion
  - use diffusion instead of active transport wherever possible



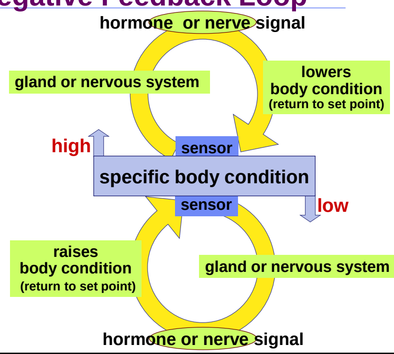
the value of a counter current exchange system

Summary

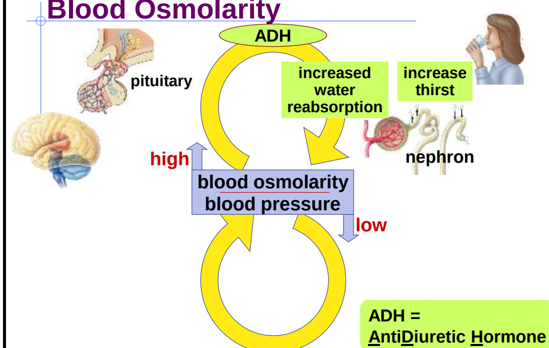
why selective reabsorption & not selective filtration?

- Not filtered out
  - cells
  - proteins
  - remain in blood (too big)
- Reabsorbed: active transport
  - Na^+
  - amino acids
  - Cl^-
  - glucose
- Reabsorbed: diffusion
  - Na^+
  - Cl^-
  - H_2O
- Excreted
  - urea
  - excess H_2O
  - excess solutes (glucose, salts)
  - toxins, drugs, "unknowns"

Negative Feedback Loop



Endocrine System Control
Blood Osmolarity

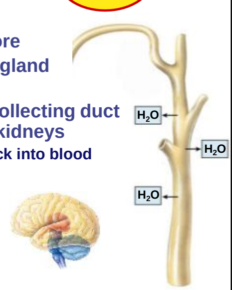


ADH = AntiDiuretic Hormone

Maintaining Water Balance

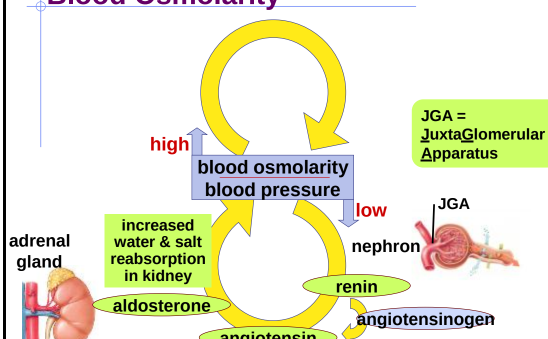
Get more water into blood fast

- High blood osmolarity level
  - too many solutes in blood
    - dehydration, high salt diet
  - stimulates thirst = drink more
  - release ADH from pituitary gland
    - antidiuretic hormone
  - increases permeability of collecting duct & reabsorption of water in kidneys
    - increase water absorption back into blood
    - decrease urination



Alcohol suppresses ADH... makes you urinate a lot!

Endocrine System Control
Blood Osmolarity



JGA = JuxtaGlomerular Apparatus

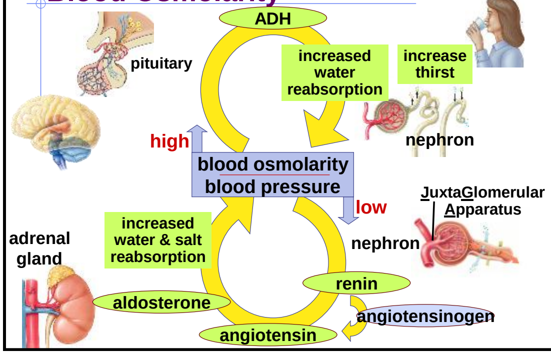
Maintaining Water Balance

Get more water & salt into blood fast!

- Low blood osmolarity level or low blood pressure
  - JGA releases **renin** in kidney
  - renin converts **angiotensinogen** to **angiotensin**
  - angiotensin causes arterioles to constrict
    - increase blood pressure
  - angiotensin triggers release of **aldosterone** from **adrenal gland**
  - increases reabsorption of NaCl & H_2O in kidneys
    - puts more water & salts back in blood

Why such a rapid response system? Spring a leak?

Endocrine System Control
Blood Osmolarity



Any Questions?