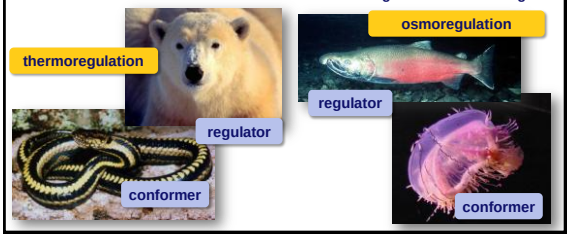
Conformers vs. Regulators

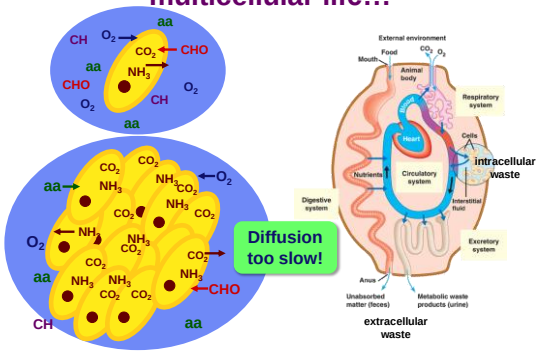
- 2 evolutionary paths for organisms
  - regulate internal environment
    - maintain relatively constant internal conditions
  - conform to external environment
    - allow internal conditions to fluctuate along with external changes



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

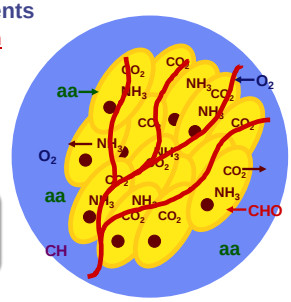
Animal systems evolved to support multicellular life…



Solving Exchange Problem

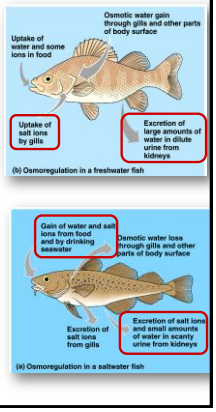
- evolution of exchange systems for
  - distributing nutrients
    - circulatory system
  - removing wastes
    - excretory system

overcoming the limitations of diffusion



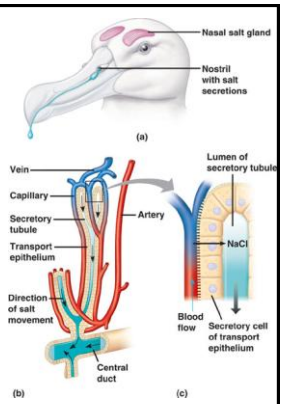
Osmoregulation

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



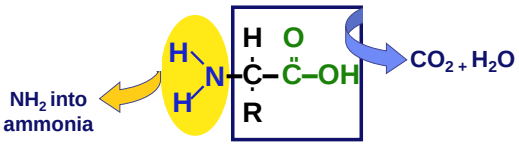
Water & Salt…

- Salt secreting glands of marine birds remove salt from blood allowing them to drink sea water during months at sea
  - secrete a fluid much more salty than ocean water



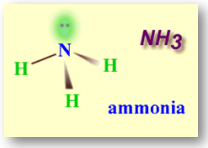
Waste Disposal

- 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
      - relatively small amount in cell

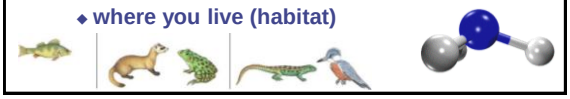


Nitrogenous Waste Disposal

- Ammonia (NH_3)
  - very toxic
    - carcinogenic
  - very soluble
    - easily crosses membranes
  - must dilute it & get rid of it… *fast!*

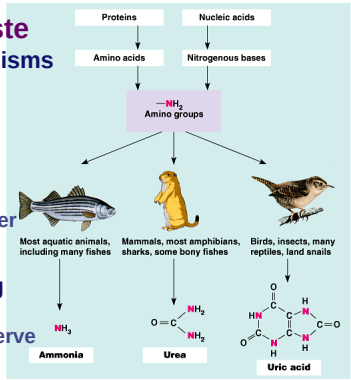


- How you get rid of nitrogenous wastes depends on:
  - who you are (evolutionary relationship)
  - where you live (habitat)



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 most water
  - uric acid
    - least toxic



Freshwater Animals

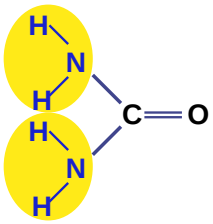
- Water removal & nitrogen waste disposal
  - surplus of water
    - can dilute ammonia & excrete it
      - need to excrete a lot of water anyway so excrete very dilute urine
    - pass ammonia continuously through gills or through any moist membrane
  - loss of salts
    - reabsorb in kidneys or active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

Land Animals

- Nitrogen waste disposal on land
  - evolved less toxic waste product
    - need to conserve water
    - urea = less soluble = less toxic
  - kidney
    - filter wastes out of blood
    - reabsorb H_2O
    - excrete waste
      - urine = urea, salts, excess sugar & H_2O
        - urine is very concentrated
        - concentrated NH_3 would be too toxic

Urea

- Larger molecule = less soluble
  - $2NH_2 + CO_2$ = urea
  - combined in liver
- Requires energy to produce
  - worth the investment of energy
- Filtered out by kidneys
  - collected from cells by circulatory system



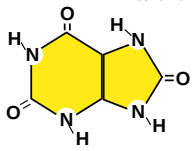
Egg-laying Land Animals

- 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



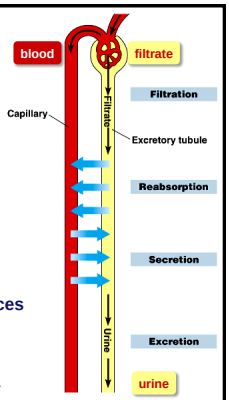
Uric Acid

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



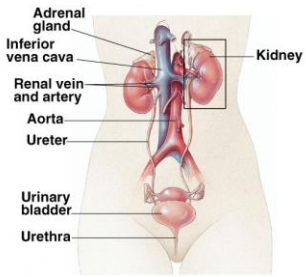
Mammalian Excretion

- Key functions
  - filtration
    - fluids from blood collected
    - includes water & solutes
  - reabsorption
    - selectively reabsorb needed substances back to blood
  - secretion
    - pump out unwanted substances to urine
  - excretion
    - remove excess substances & toxins from body

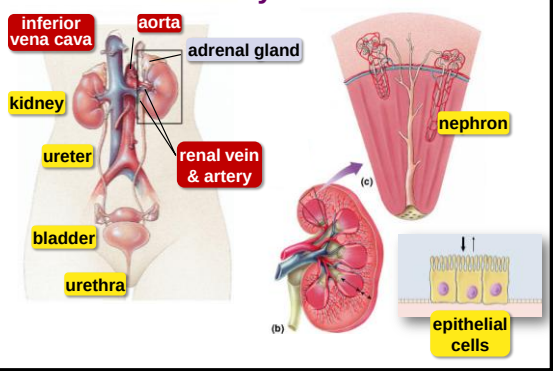


Mammalian Kidney

- Urinary system filters blood & helps maintain water balance (osmoregulation)
  - pair of bean-shaped kidneys
  - supplied with blood
    - renal artery
    - renal vein

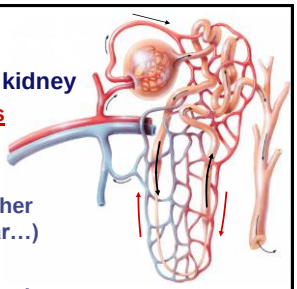


Mammalian Kidney



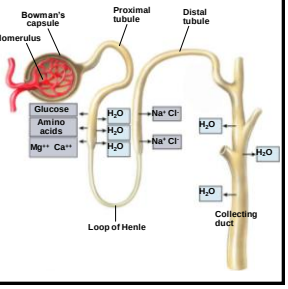
Nephron

- Functional units of kidney
  - 1 million nephrons per kidney
- Function
  - filter out urea & other solutes (salt, sugar…)
- Process
  - blood plasma filtered into nephron
  - selective reabsorption of valuable solutes & H_2O



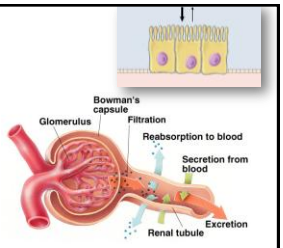
Mammalian Kidney

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



Nephron: Filtration

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

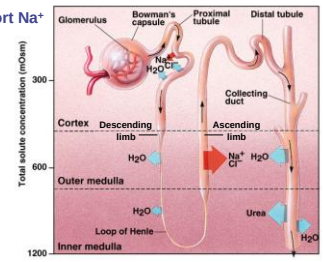


high blood pressure in kidneys force to push H_2O & solutes out of blood vessel

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

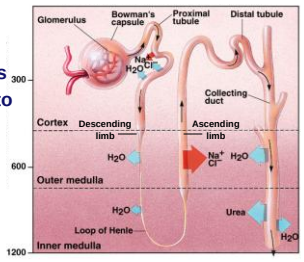
Nephron: Re-absorption

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



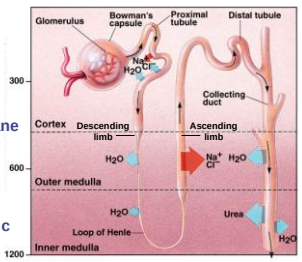
Nephron: Re-absorption

- Loop of Henle
  - descending limb
    - high permeability to H_2O
    - many aquaporins in cell membranes
    - low permeability to salt
  - reabsorbed
    - H_2O



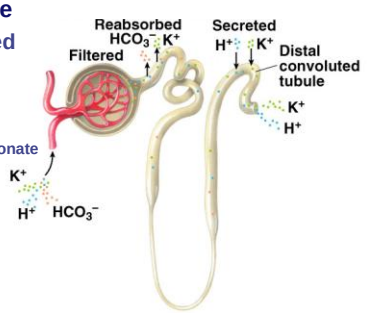
Nephron: Re-absorption

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



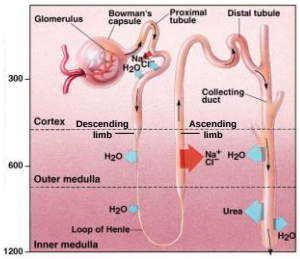
Nephron: Re-absorption

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



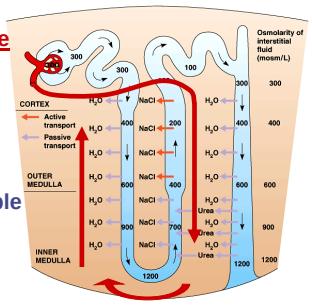
Nephron: Reabsorption & Excretion

- Collecting duct
  - reabsorbed
    - H_2O
  - excretion
    - urea passed through to bladder



Osmotic Control in Nephron

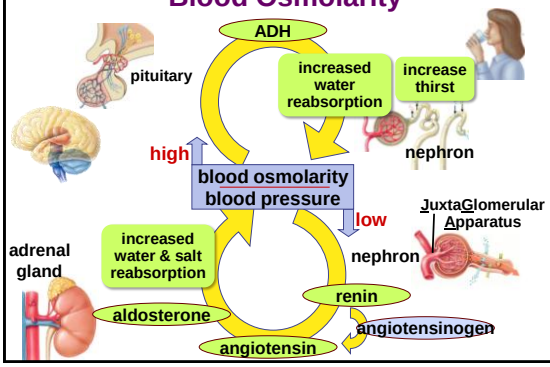
- How is all this re-absorption achieved?
  - tight osmotic control to reduce the energy cost of excretion
  - use diffusion instead of active transport wherever possible



Summary

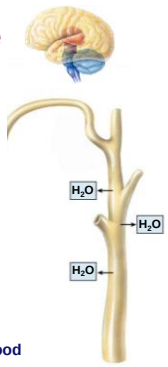
- Not filtered out
  - remain in blood (too big)
  - cells
  - proteins
- Reabsorbed: active transport
  - Na^+
  - amino acids
  - Cl^-
  - glucose
- Reabsorbed: diffusion
  - Na^+
  - Cl^-
  - H_2O
- Excreted
  - urea (highly concentrated)
  - excess H_2O
  - excess solutes (glucose, salts)
  - toxins,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

Endocrine System Control Blood Osmolarity



Maintaining Water Balance

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



Maintaining Water Balance

- 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