1

Osmoregulation & Excretion
Chapter 44

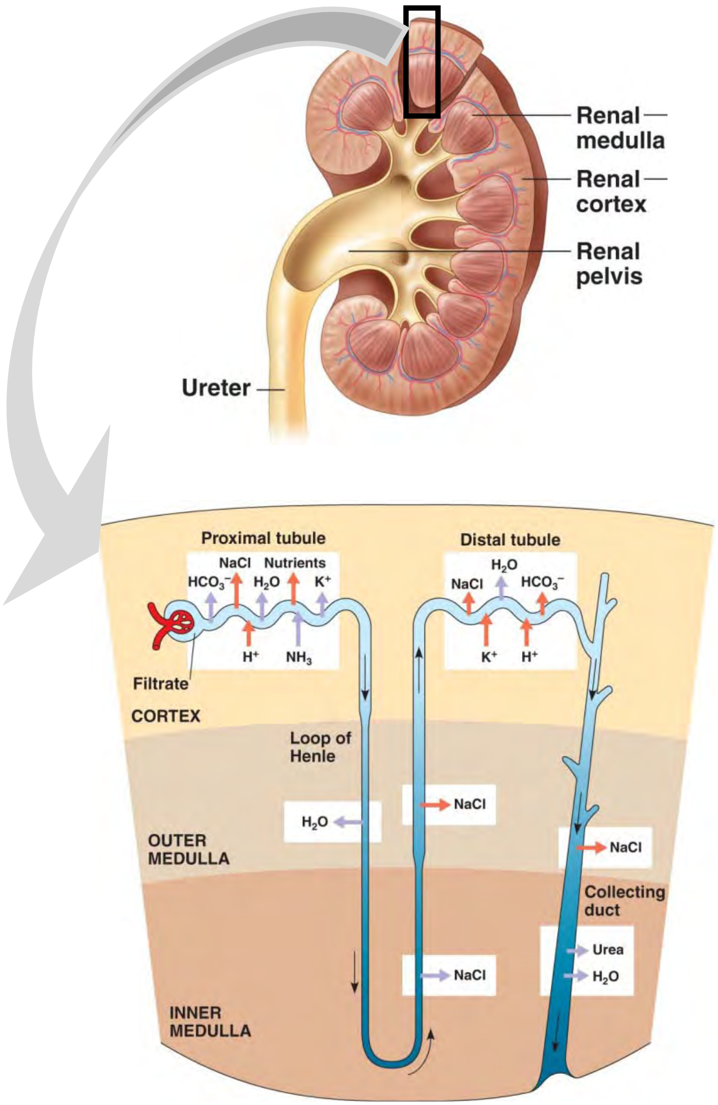


Figure 44.15 (Campbell 9th ed.)

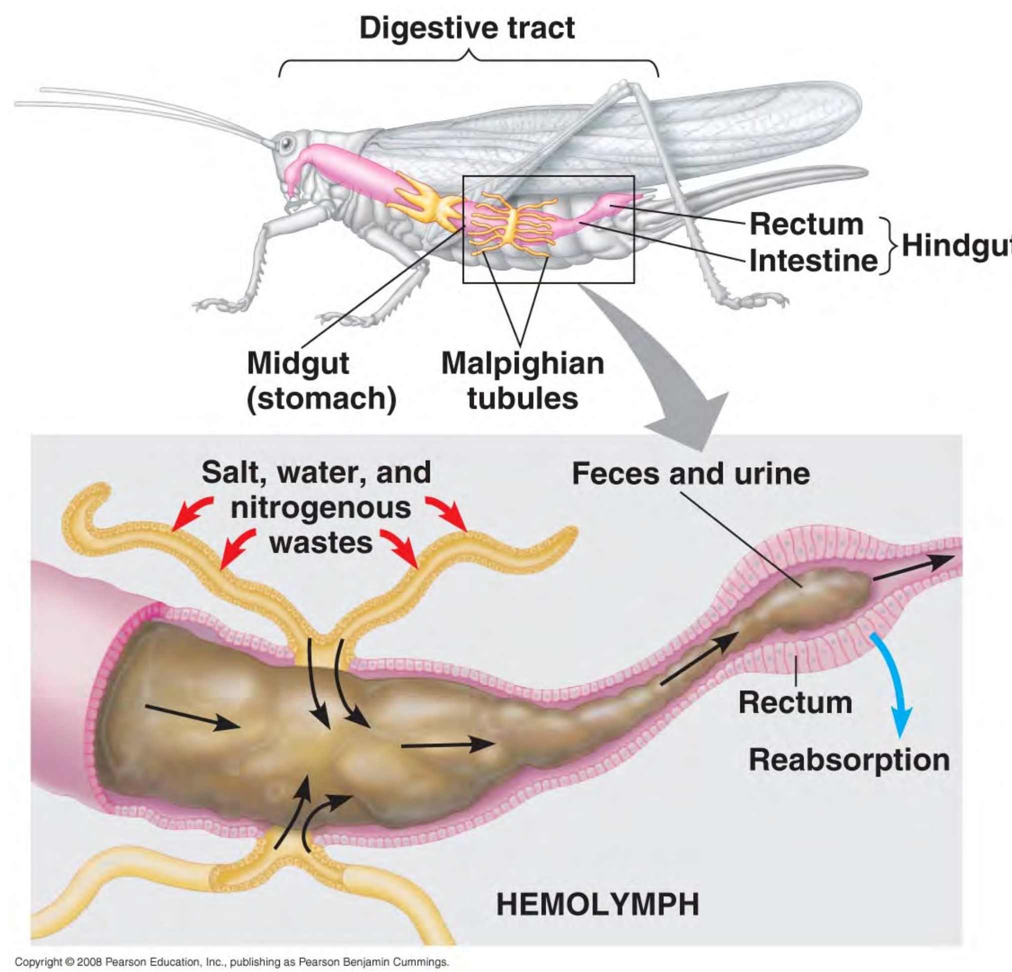


Figure 44.13 (Campbell 9th ed.)

2

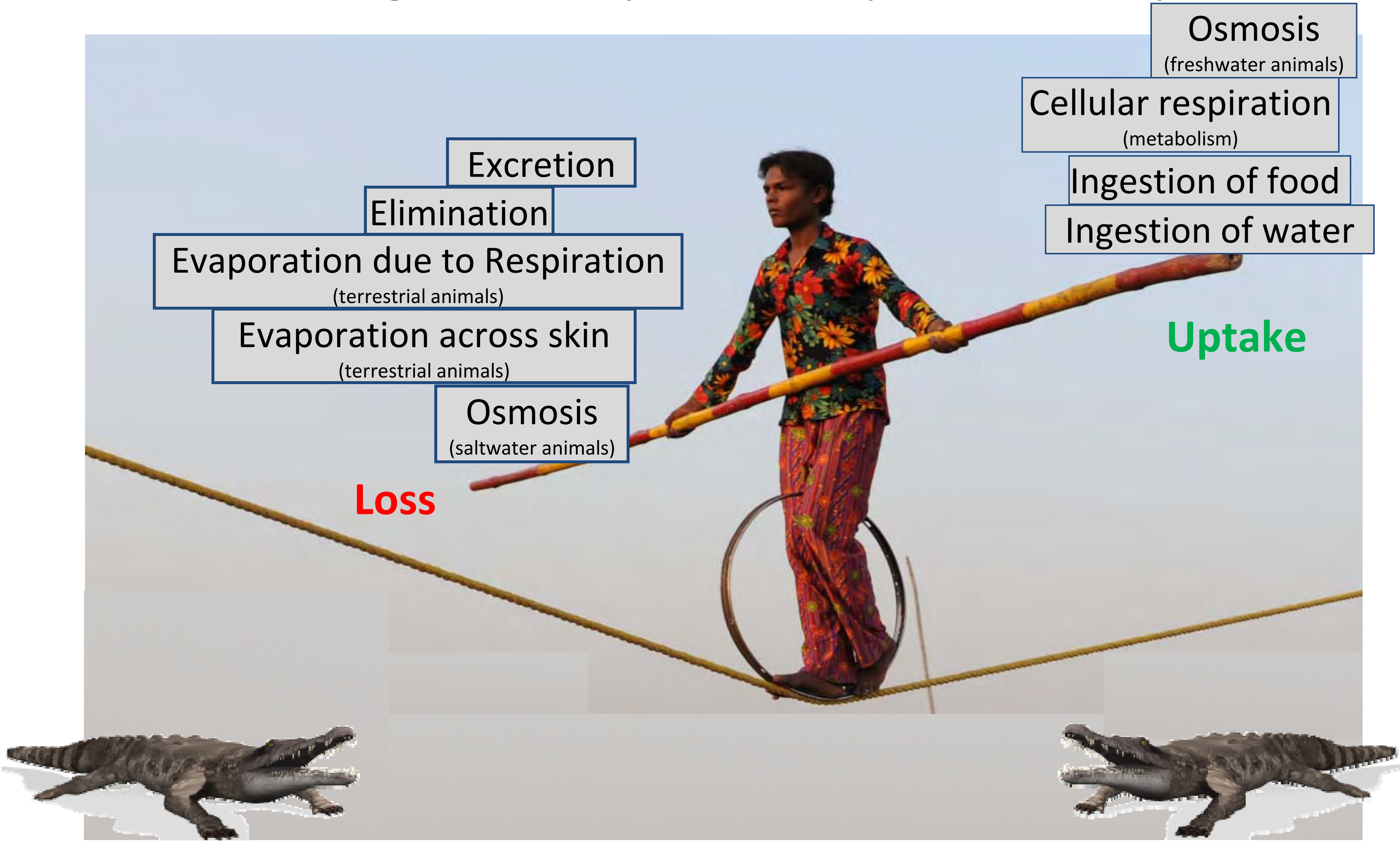
Excretory system

The organs and processes which
regulate water level and ion concentrations (osmoregulation)
and remove nitrogenous waste (excretion).

3

Osmoregulation

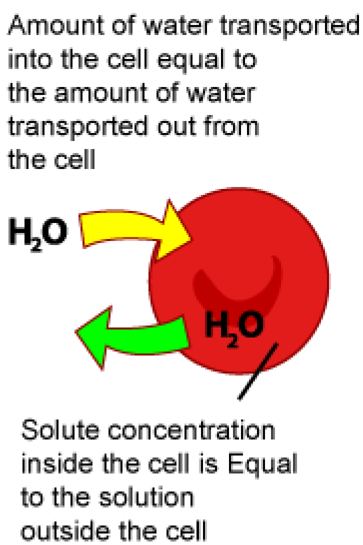
Balance of uptake and loss of water AND solutes
to regulate body fluid composition and pH



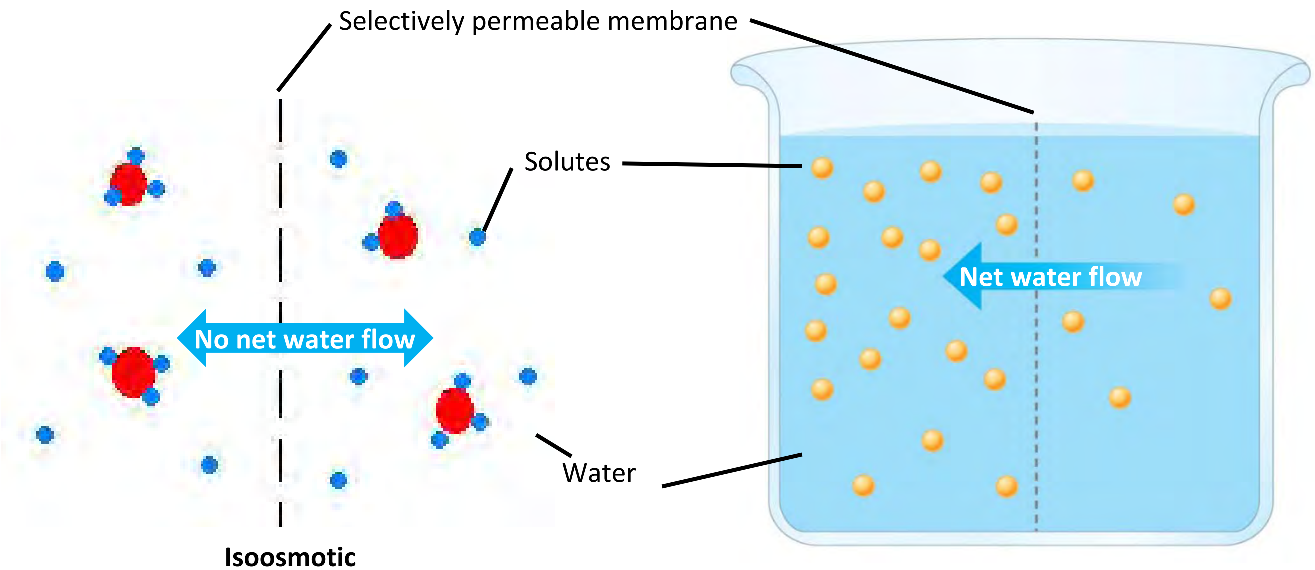
Osmosis

Differences in solute concentrations on 2 sides of a selectively permeable membrane result in movement of water from areas of lower solute concentration to higher concentration

Selectively permeable membrane (SPM) prevents the movement of solutes via diffusion, so H_2O must move instead



Isoosmotic (isotonic)



Isoosmotic (isotonic)

Hyperosmotic (hypertonic)

Hypoosmotic (hypotonic)

- Hyperosmotic, hypoosmotic and isoosmotic are all comparisons of the 2 sides of the SPM
  i.e. The left side is hyperosmotic AS COMPARED TO the right side so H_2O moves from right to left
  i.e. The left side has a > solute concentration AS COMPARED TO the right side so H_2O moves from right to left
  i.e. The left side is isoosmotic AS COMPARED TO the right side so equal amounts of water move in both directions

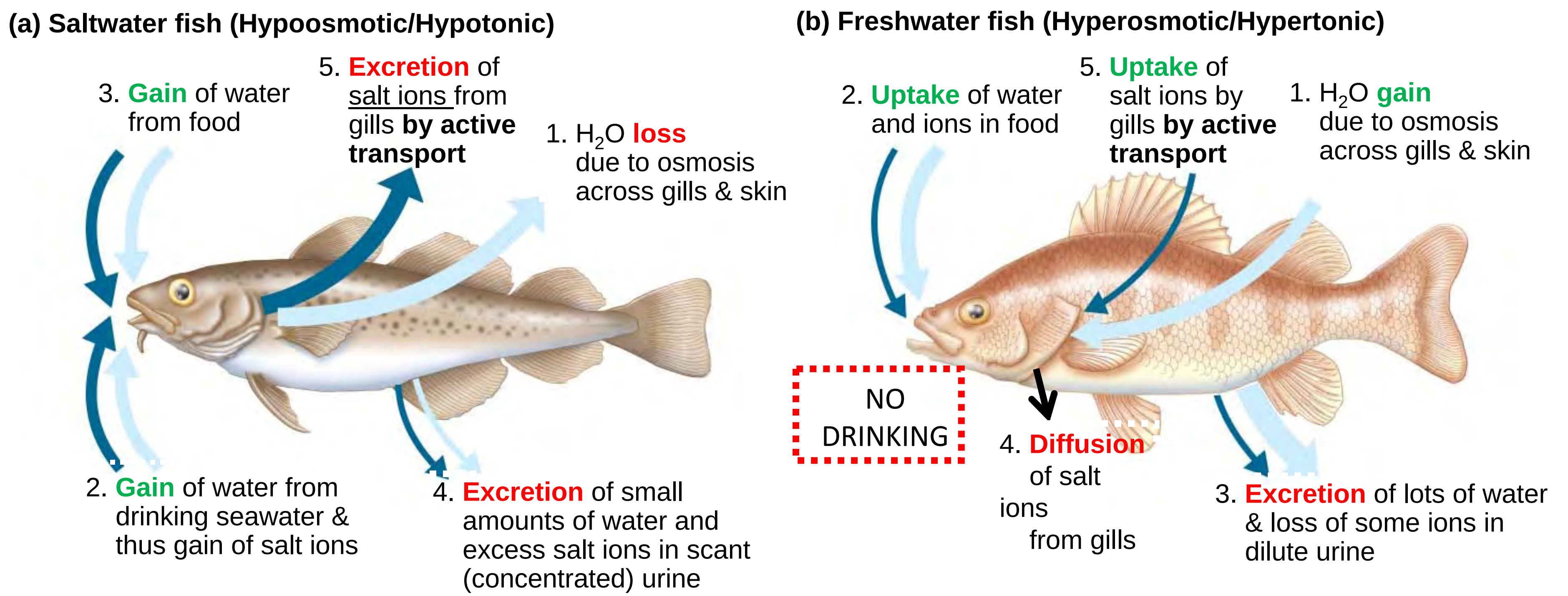
http://www.one-school.net/Malaysia/UniversityandCollege/SPM/revisioncard/biology/movementacrossmembrane/images/isotonicbloodcell.png

Figure 44.2 and 7.14 (Campbell 9th ed.)

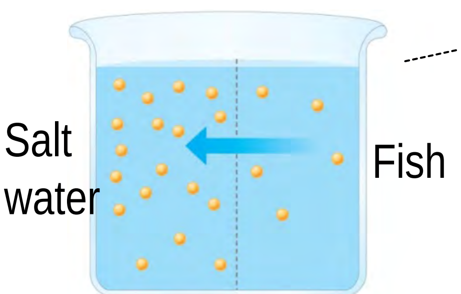
Osmoregulation in fish

Passive movements of water (osmosis) cause imbalance.

Drinking, eating, excretion & active transport compensate for gains/losses



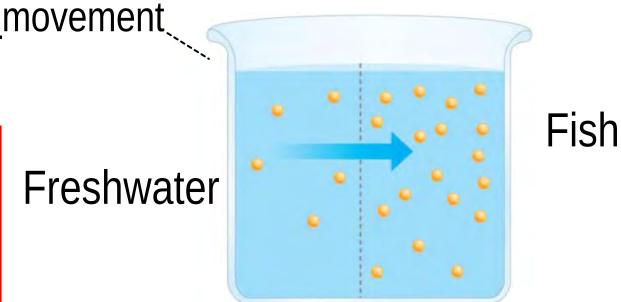
NOTE Arrow ( ) indicates direction of WATER movement (i.e. osmotic gradient)



Saltwater fish is hypotonic to H_2O

BE CLEAR on dif btwn fresh & saltwater fish!!!

Figure 44.3 (Campbell 9th ed.)



Freshwater fish is hypertonic to H_2O

7

Diadromous Fish

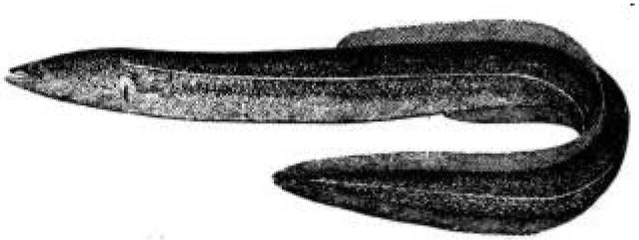
Switch btwn fresh and salt water at different times of life

MUST be able to adjust their physiology
to deal with being hypo- or hypertonic at different times in their life.

Anadromous fish
hatch/born in freshwater, live in saltwater, and return to freshwater to breed

e.g. salmon, cod, sturgeon,
lamprey, shad,
herring, striped bass

Catadromous fish
Hatch/born in saltwater,
live in freshwater,
& return to saltwater to breed



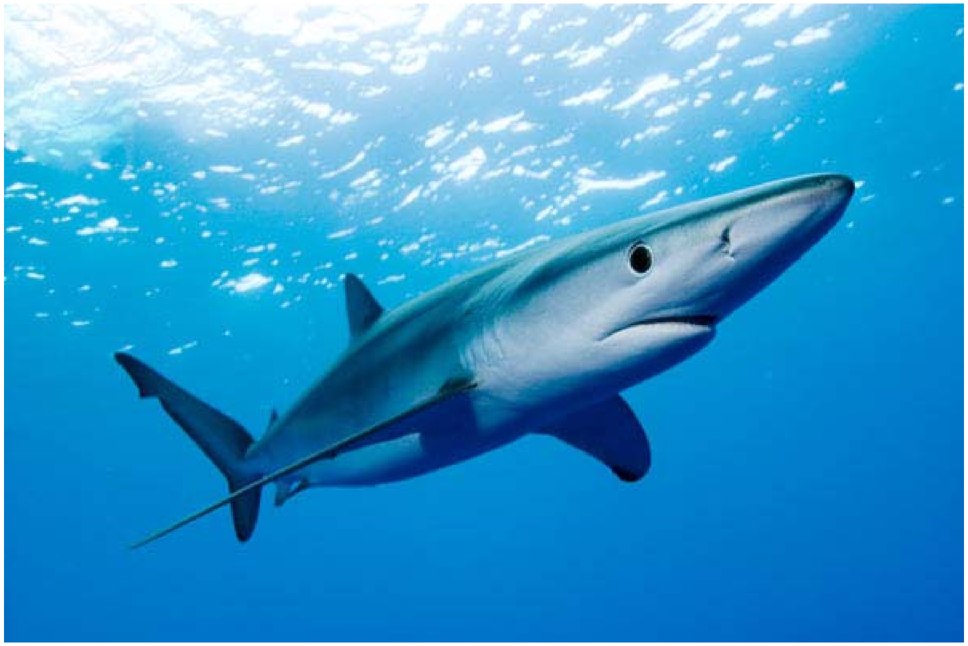
e.g. many eels (not lamprey),
mullet, scorpionfishes, snook

Figure 44.4 (Campbell 9th ed.)

8

Osmoregulation in Elasmobranchs

Unlike most saltwater fish, sharks, skates, & rays reduce osmotic H_2O loss by increasing blood solute concentration above seawater



Urea and TMAO are nitrogen-containing break-down products of protein metabolism.

Urea is toxic to animals.

Rather than excreting all urea and TMAO, Elasmobranchs add some to their tissues.

a. > [ion] prevents osmotic H_2O loss

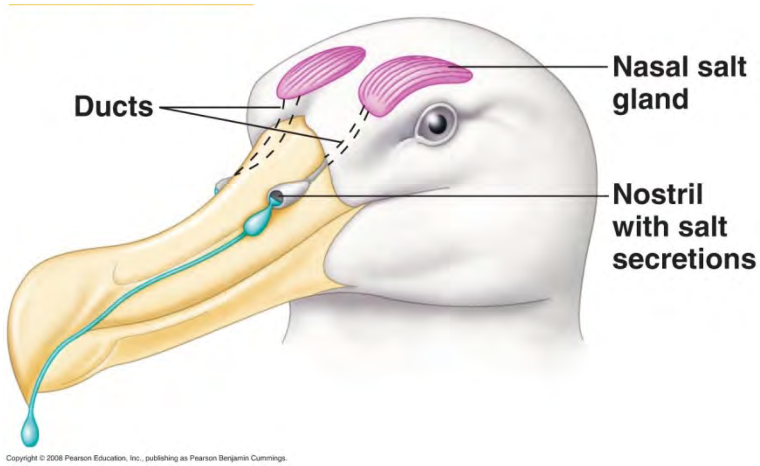
b. TMAO protects tissues from urea damage

TMAO = trimethylamine oxide

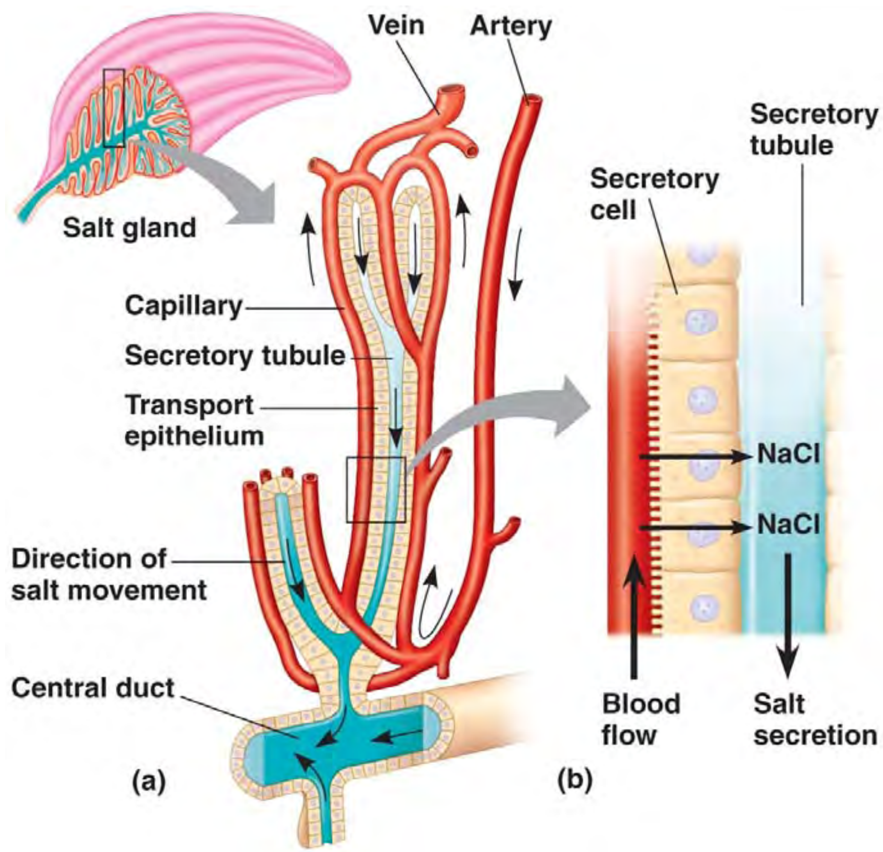
Osmoregulation

9

Salt glands remove excess salt from the blood in some animals



Nasal glands found in many seabirds are secretory tubules surrounded by capillaries.



- Secretory cells of the secretory tubules actively transport salt from the blood to the tubule via <u>countercurrent circulation</u>

Figure 44.7 (Campbell 9th ed.)

10

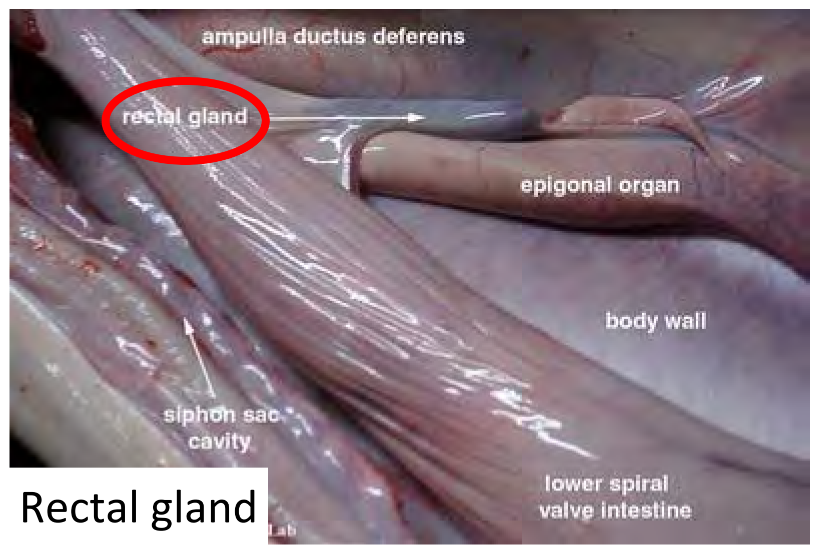
Osmoregulation

Many marine animals have salt glands in different locations

Tear duct

Nasal duct

Lingual glands

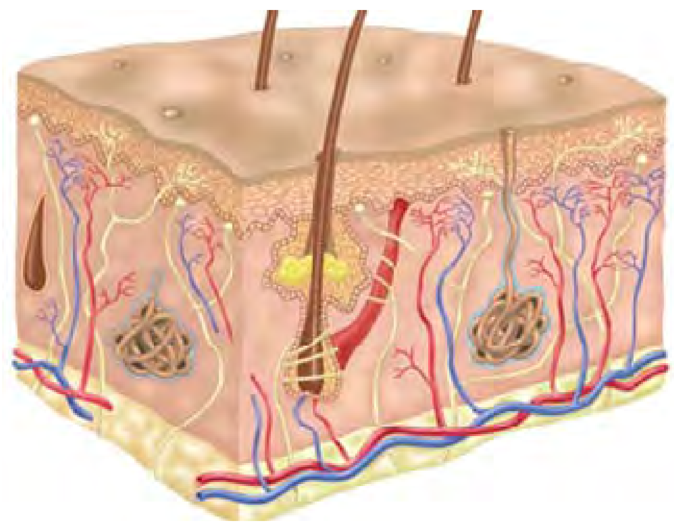


Rectal gland

11

Osmoregulation in land animals

Exoskeleton and skin (and scales?) reduce water loss



12

Osmoregulation in land animals

Fur and feathers reduce water loss by trapping moisture

Excretory system

The organs and processes which
regulate water level and ion concentrations (osmoregulation)
and **remove nitrogenous waste (excretion).**

Excretion is the removal of nitrogenous byproducts of metabolism from cells

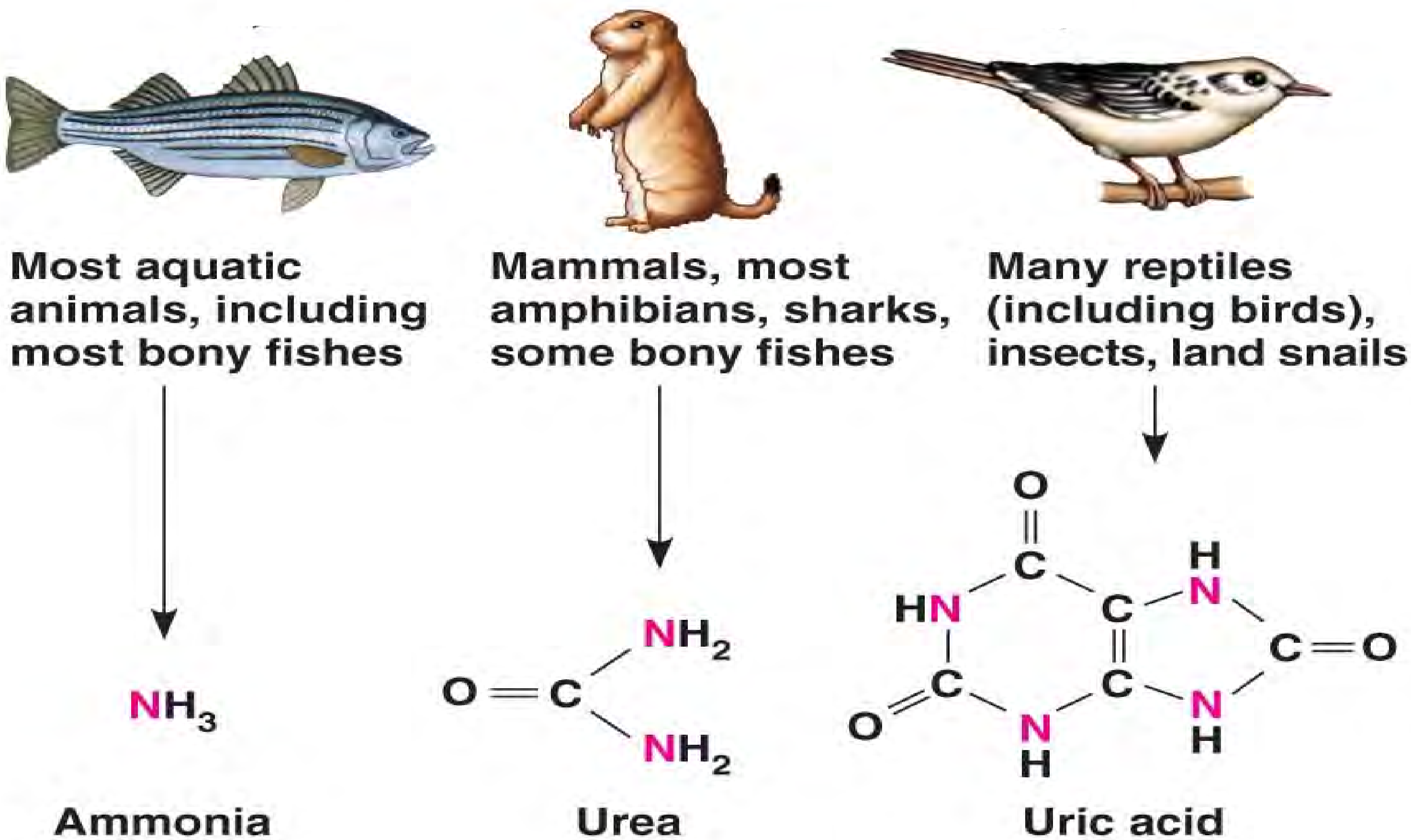
vs.

Elimination is the removal of undigested food from the digestive tract

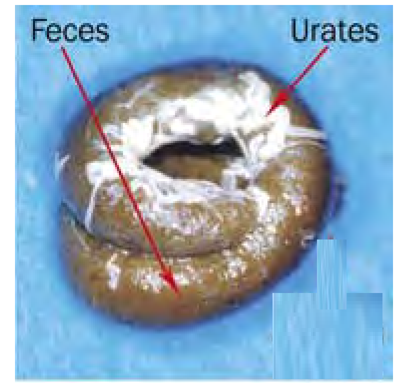
23

Nitrogenous Wastes

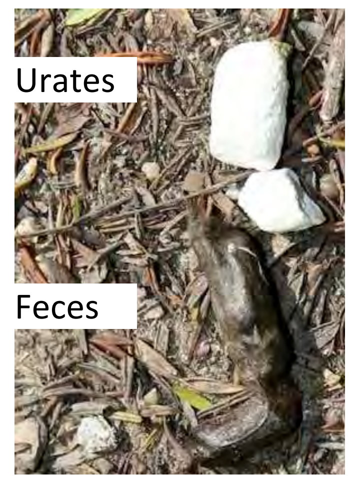
Byproducts of metabolism converted to 1 of 3 nitrogenous forms <u>in the liver</u>



Birds



Snakes



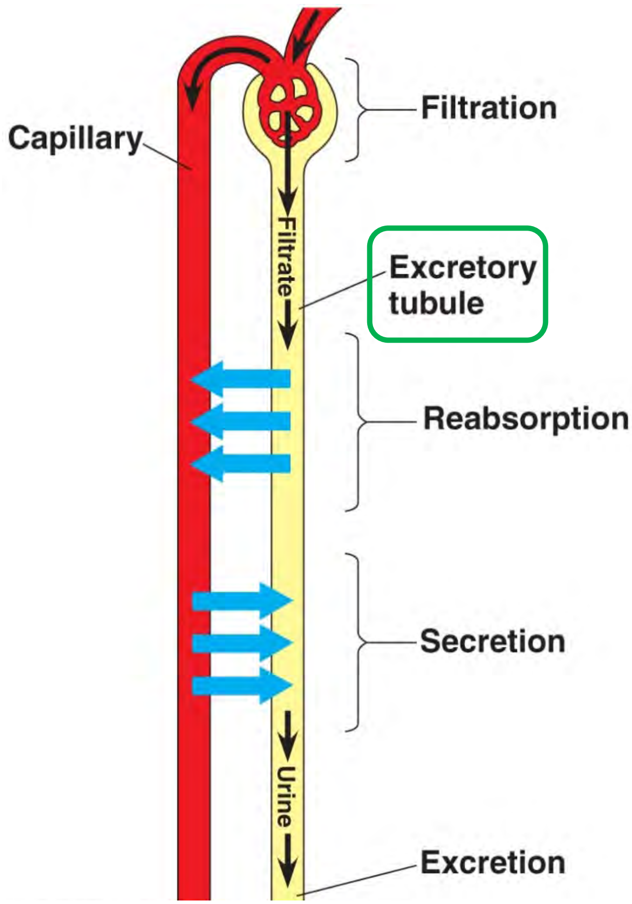
- Very toxic
- Must be diluted to transport in blood for excretion across gills
- Cannot be stored

Figure 44.8 (Campbell 9th ed)

- Much less toxic (100,000x)
- Conserves water
- More energy to produce
- Can occur in [higher] in blood for excretion by kidney
- Can be stored in bladder

- Least toxic
- Most energy to produce
- Conserves most water
- Can occur in [higher] in blood for excretion by kidney (not stored since no bladder)
- Good for storage in amniotic egg

24 Tubular Theme in Excretory systems



Transport epithelium

Figure 44.10 (Campbell 9th ed.)

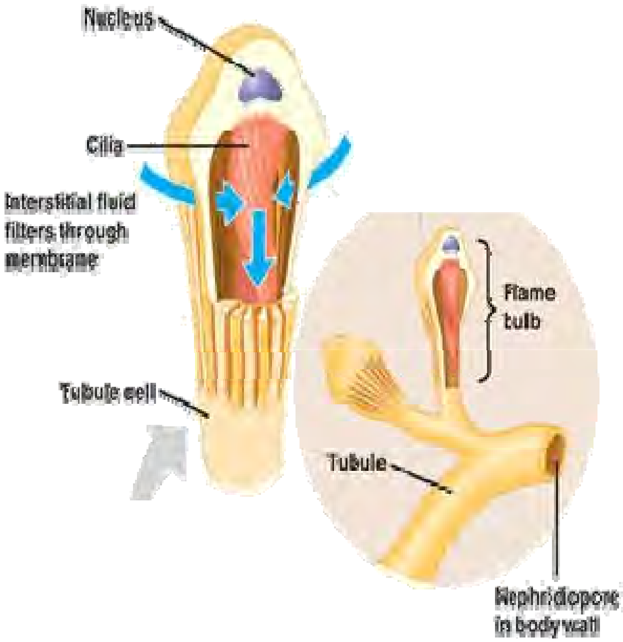
All excretory systems are made of many tubules which vary in size, shape and function depending on the organism

4 main types of excretory systems:

1. Protonephridia
2. Metanephridia
3. Malpighian tubules
4. Kidneys

25

Flatworms use Protonephridia for osmoregulation but NOT for excretion



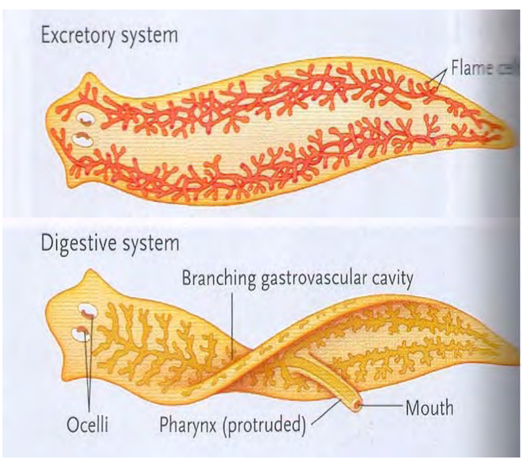


Figure 44.11 (Campbell 9th ed.)

http://www.biology.ualberta.ca/courses.hp/zool250/animations/Excretion.swf

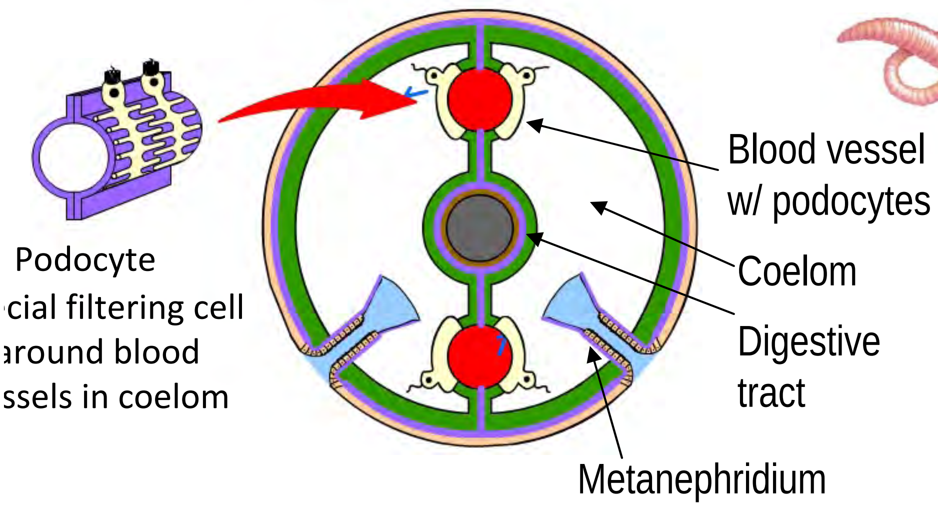
Parts of a Protnephridium:

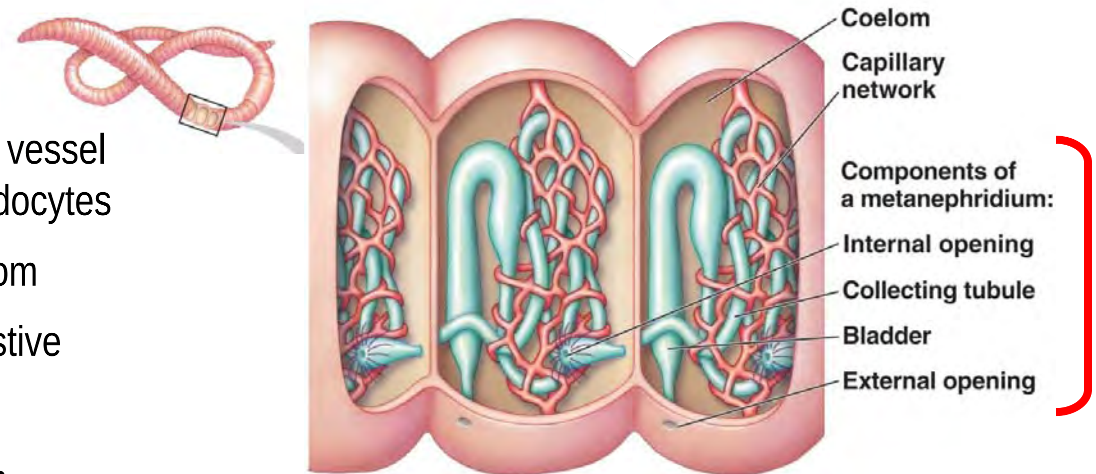
1. Flame bulb w/ slits and internal cilia
   - Selectively filters interstitial fluid (IF)
     - Cilia draws in H_2O & small molecules and propels filtrate through tubules
2. Tubules – lead to outside
   - Along way tubules reabsorb needed ions back into interstitial fluids
   - Expel remaining filtrate via pores in body wall
     - Fluid is mainly H_2O

Protonephridia
- (1) filter IF; (2) reabsorb ions; (3) expel H_2O
- are involved in osmoregulation but not excretion
  - Most NH_3 diffuses out across body wall or into GVC and out mouth

26

Most annelids use Metanephridia for osmoregulation AND excretion





- Blood vessels running through the coelom have walls made of special slitted cells (podocytes).
  - Podocytes unselectively filter water, many nutrients and waste products from blood into coelomic fluid.
- In the coelomic fluid are Metanephridia comprised of open-ended funnels connected to tubes to outside.
- Propelled by cilia, coelomic fluid flows into open-ended funnels then tubes and:
  - needed H_2O & nutrients are reabsorbed from fluids by tubes & into surrounding blood vessels;
  - unneeded substances (H_2O and NH_3) are excreted via pores in body wall.

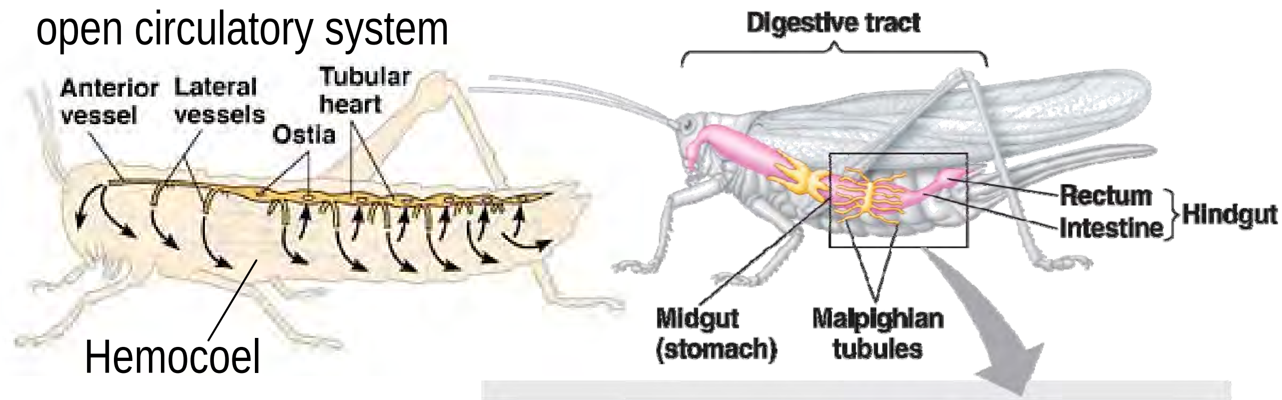
- Metanephridia:
  - reabsorb and excrete but do NOT filter wastes from blood (podocytes filter blood)
  - are involved in both osmoregulation and excretion

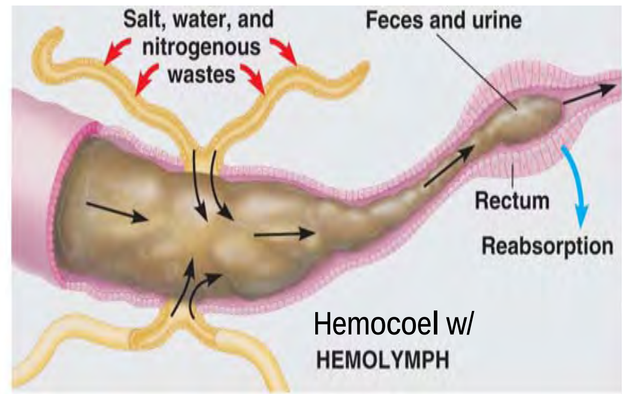
http://www.biology.ualberta.ca/courses.hp/zool250/animations/Excretion.swf

Figure 44.12 (Campbell 9th ed.)

Insects use Malpighian Tubules for osmoregulation AND excretion

open circulatory system





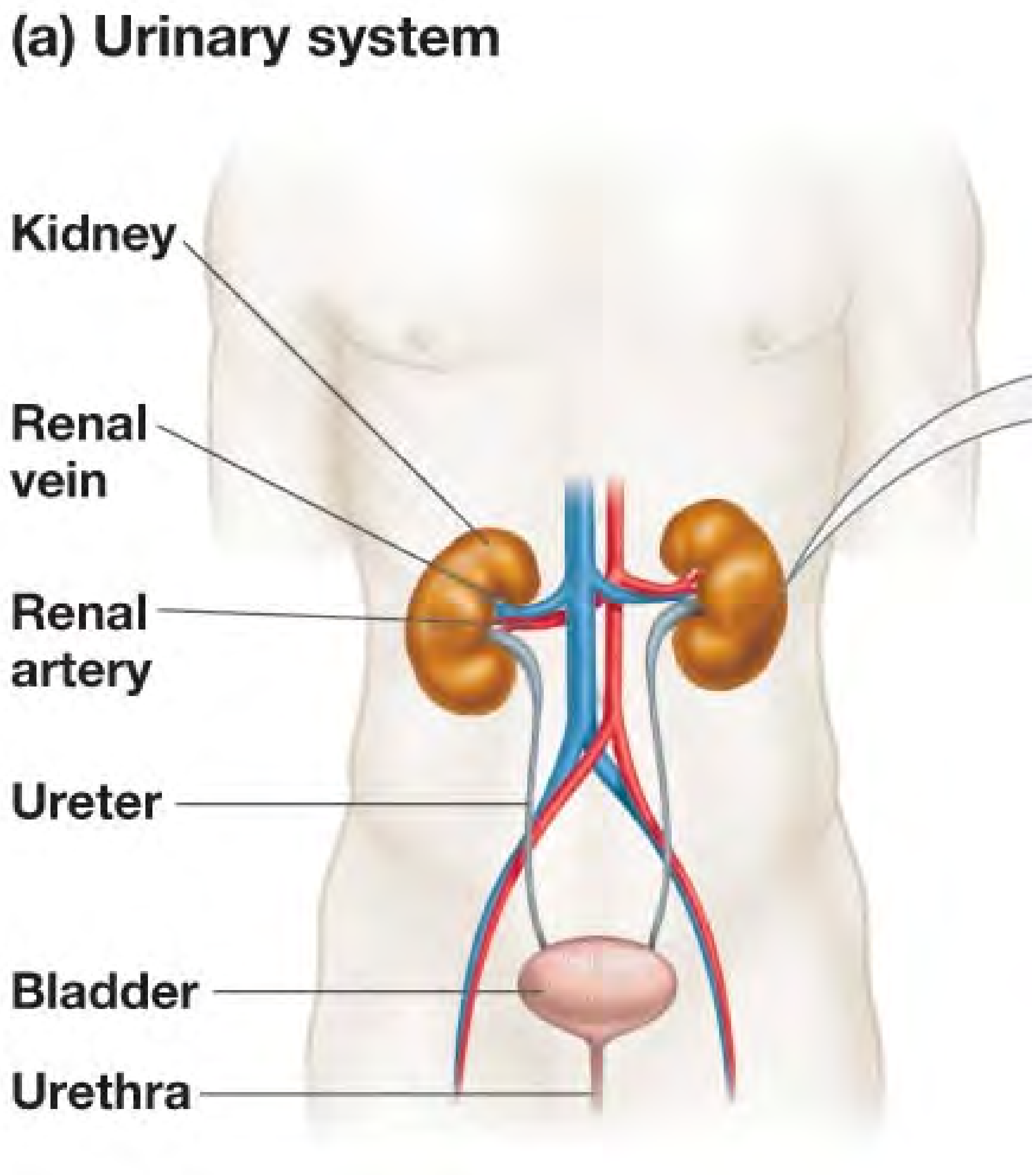
- Malpighian tubules are outfoldings of stomach (midgut) extending into **hemocoel**.
    - a. epithelial cells absorb salt from hemolymph and secrete it into lumen of tubule;
    - b. H_2O follows into lumen via **osmosis**;
    - c. NH_3 & other solutes follow into lumen via **diffusion;**
- H_2O, NH_3, and other solutes empty into stomach (midgut) mixing w/ digesting food;
- In rectum (hindgut):
    - a.solutes pumped back into hemolymph
    - b.reabsorption of H_2O follows via osmosis
- Dry fecal pellet containing undigested food and uric acid eliminated

- While malpighian tubules are involved in both osmoregulation AND excretion they DO NOT filter, reabsorb, or excrete
    - Reabsorption and excretion occur in the rectum

Figure 44.13 (Campbell 9th ed.)

28

Vertebrates use Kidneys for osmoregulation AND excretion



Refer to Figure 44.14 (Campbell 9th ed.)

29

Kidney Function

Kidneys filter total blood volume <u>300 times</u> per day

Produces 180 L of filtrate

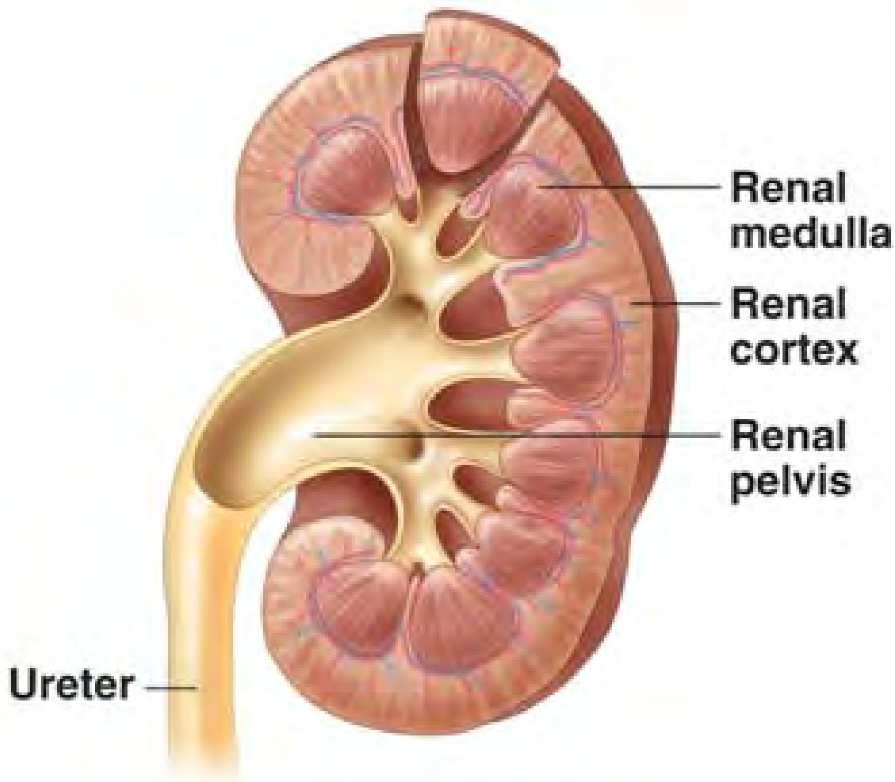
Reaborbs 95% of filtrate

Excretes 1.5L

30

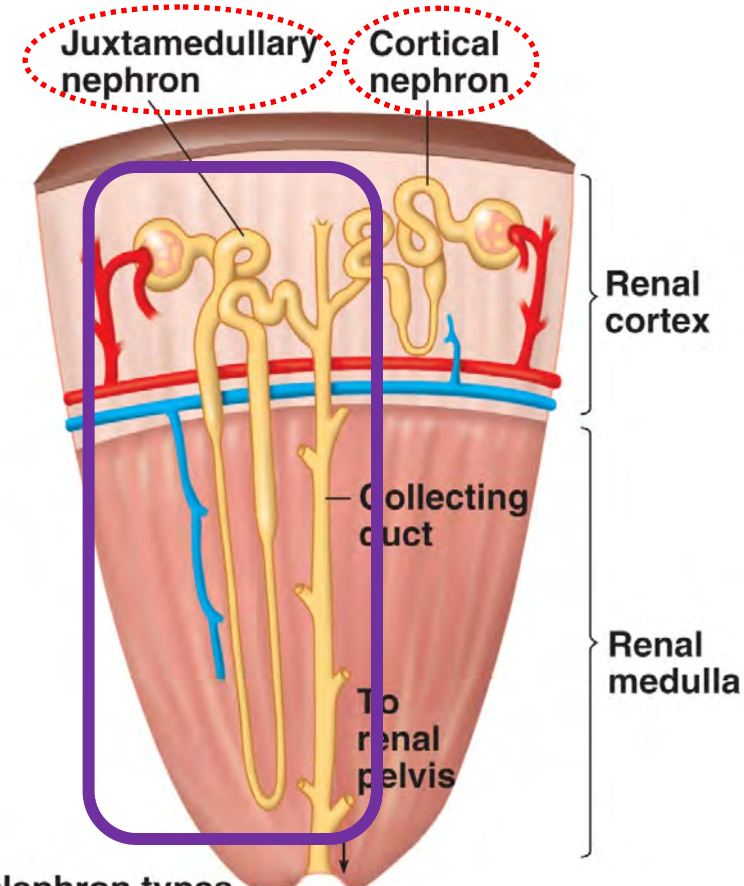
Kidney Structure

3 parts



Kidney structure

Nephron is the basic functional unit



(c) Nephron types

- ~ 1,000,000 nephrons per human kidney
- Only 15% juxtamedullary nephrons but critical to H_2O reabsorption

Figure 44.14 (Campbell 9th ed.)

Nephron Structure

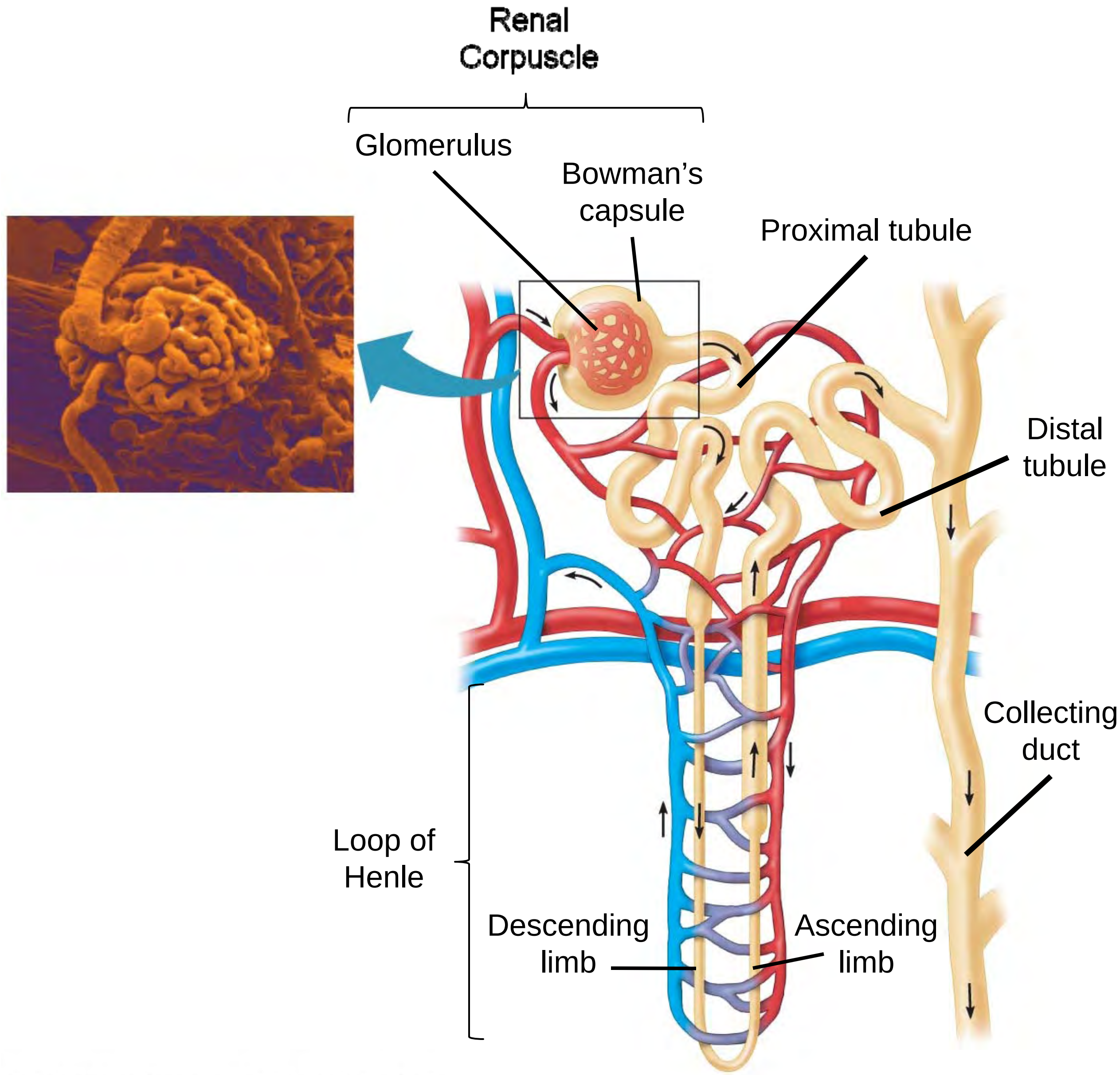


Figure 44.14 (Campbell 9th ed.)

32

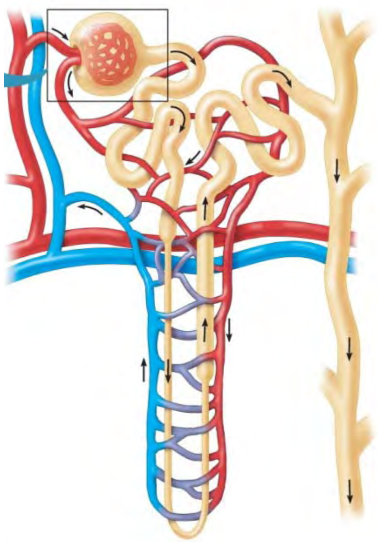
Nephron Function

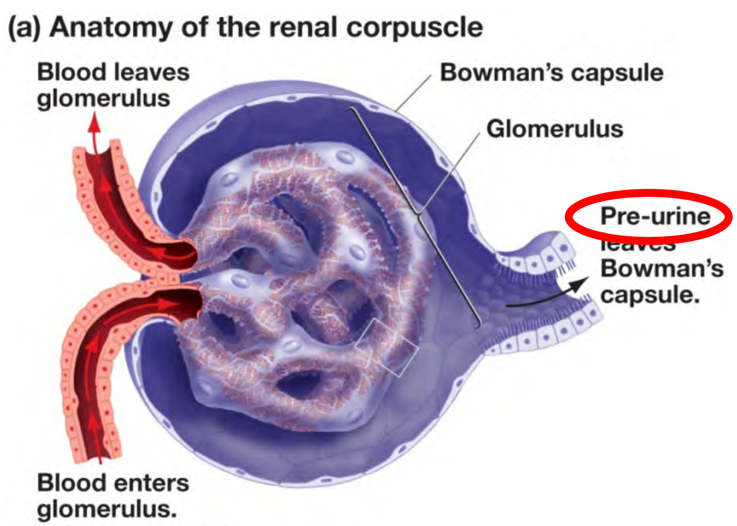
Renal corpuscle = glomerulus + Bowman’s capsule

Function: Filtration

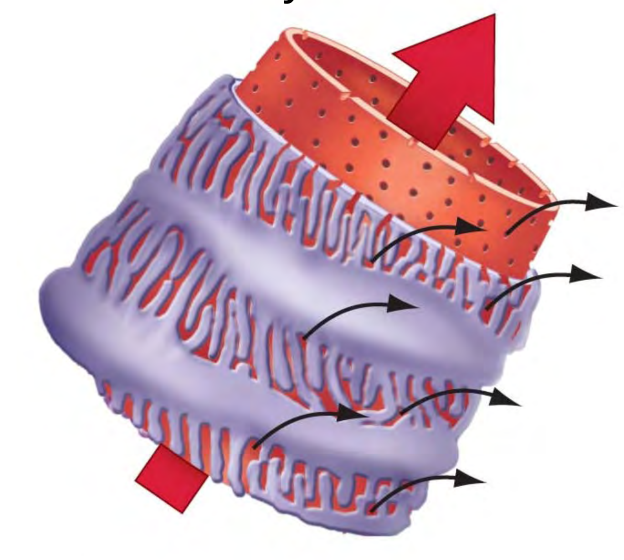
Special cells, <u>podocytes</u>, wrap around glomerulus capillaries & **<u>filter</u>** blood into bowman’s capsule

- filtrate includes H_2O and all SMALL molecules in blood including
  NaCl, urea, glucose, vitamins, amino acids
- Filtrate known as “pre-urine” since much processing yet to occur





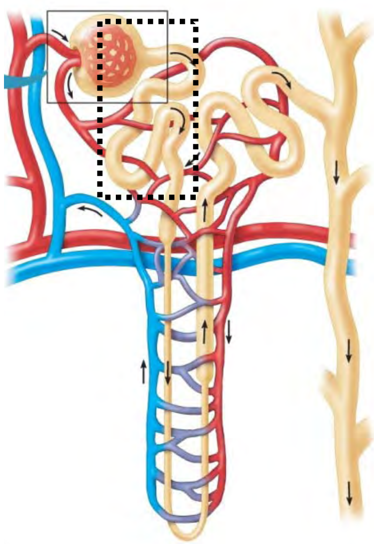
Podocyte



33

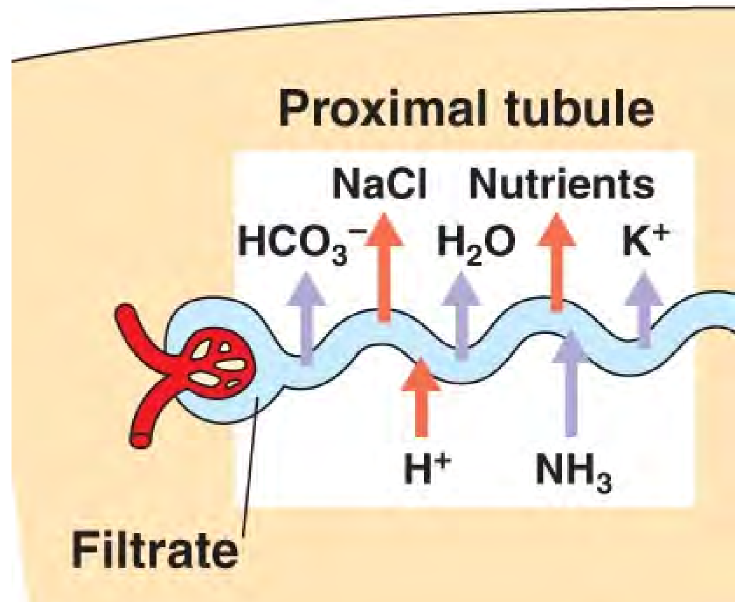
Nephron Function

Proximal tubule



Reabsorption of most of the pre-urine filtrate:

- H_2O
- Na^+, Cl^-,
- Nutrients
  - glucose, AAs, vitamins



pH Balance

- H^+
- Bicarbonate (HCO_3^-)

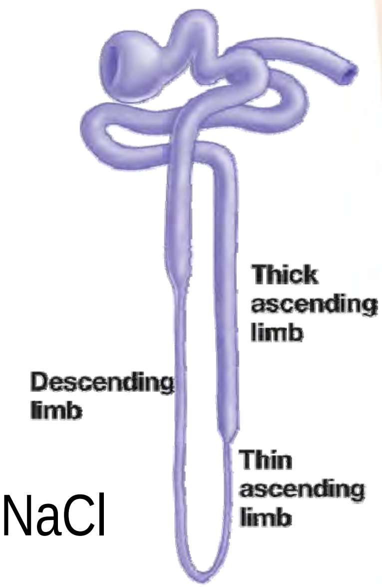
Figure 44.15 (Campbell 9th ed.)

35

Nephron Function

Loop of Henle

- **Descending Limb -** Reabsorption of most H_2O
  - ONLY Permeable to H_2O NOT NaCl or other solutes
  - H_2O exits passively (osmosis) due to high [NaCl] in surrounding tissues
  - Filtrate [ion] increases as it proceeds down descending limb
- **Ascending limb -** Reabsorption of most NaCl
  - Permeable to Na^+ & Cl^- but NOT H_2O
  - Na^+ & Cl^- exit
    - Thin portion – via diffusion
    - Thick portion – via active transport
  - Establishes osmotic gradient in tissue around descending limb.



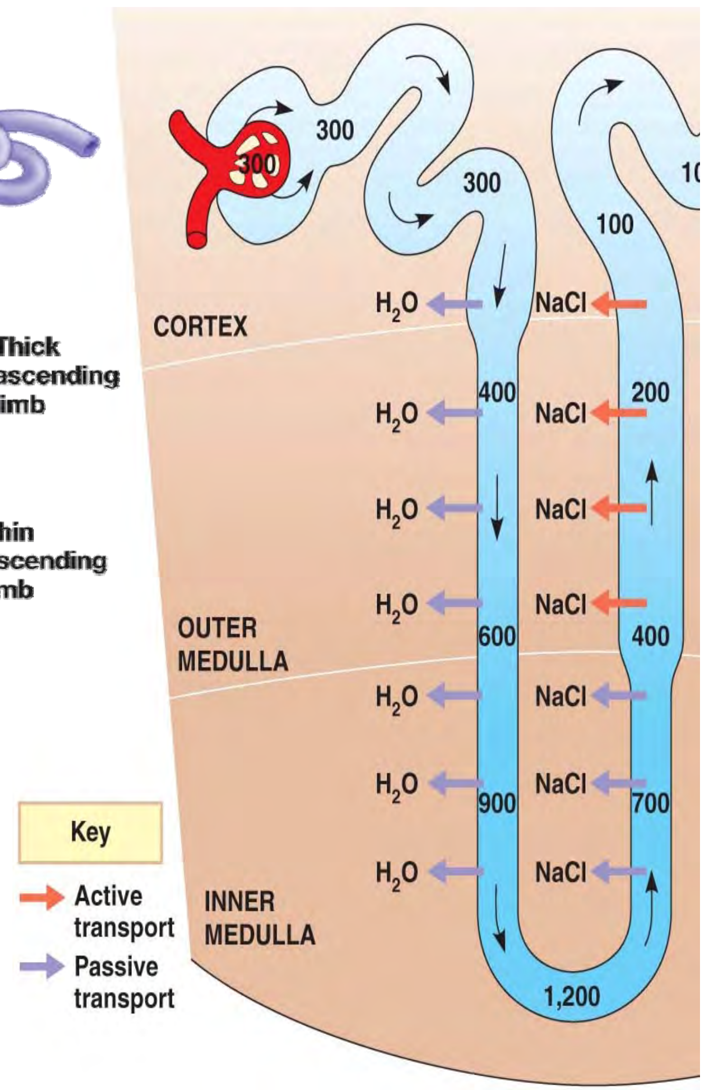


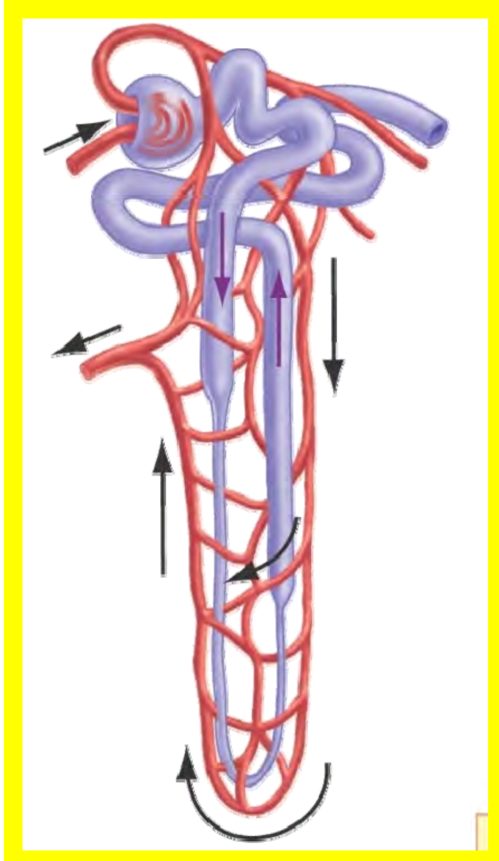
Figure 44.16 (Campbell 9th ed.)

36

Nephron Function

Loop of Henle

- Vasa Recta
  - group of capillaries that returns H_2O and NaCl from tissues surrounding Loop of Henle back to blood



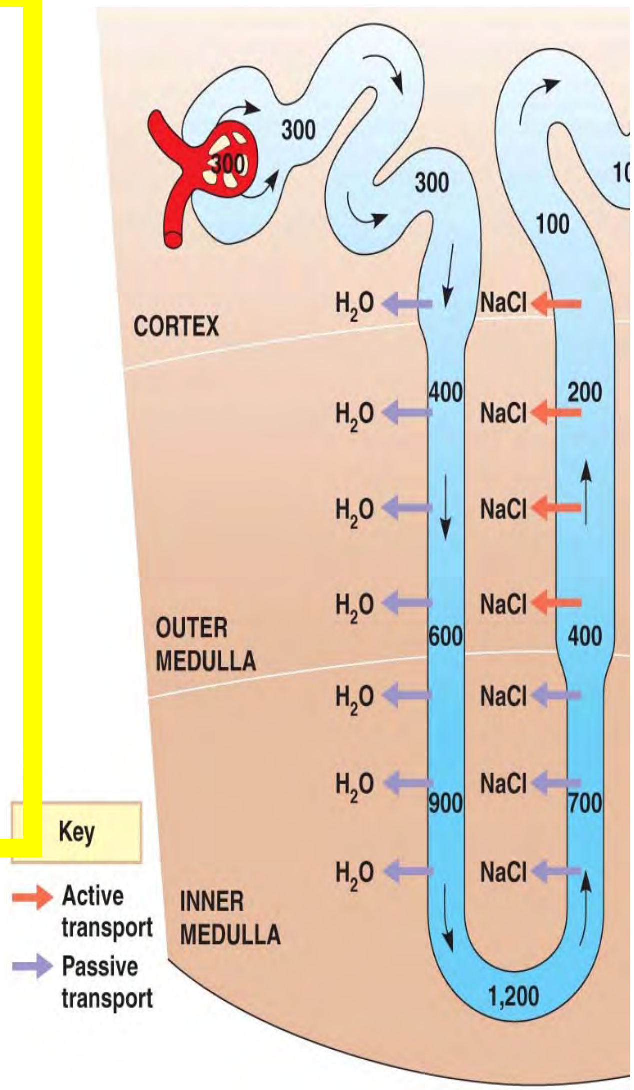
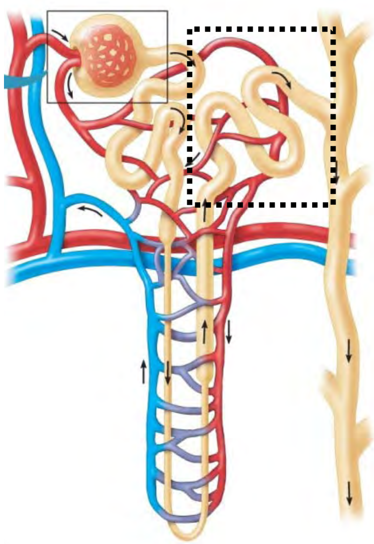


Figure 44.14 (Campbell 9th ed.)

Nephron Function

Distal tubule



Reabsorption

- H_2O
- NaCl
- K^+

pH balance

- H^+
- Bicarbonate (HCO_3^-)

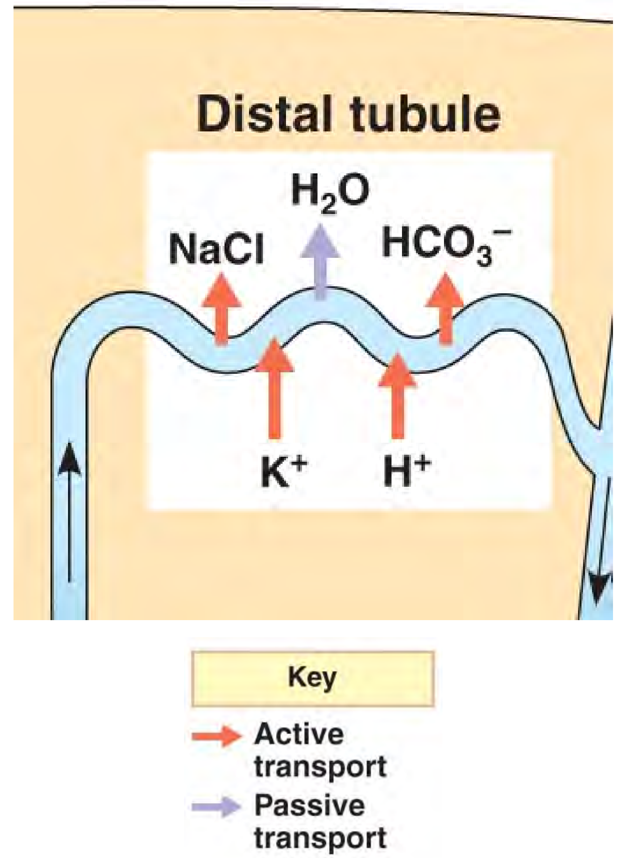
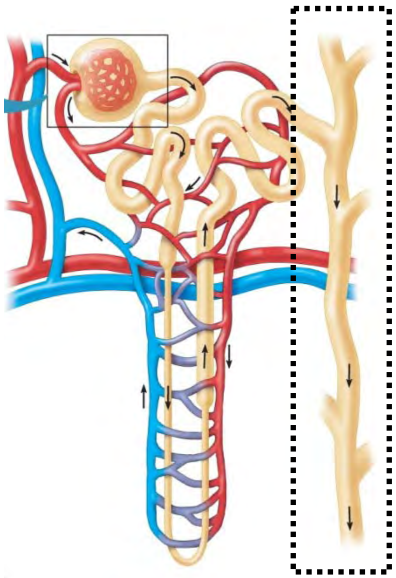


Figure 44.15 (Campbell 9th ed.)

Nephron Function

Collecting duct



Reabsorption

- H_2O
- maybe NaCl

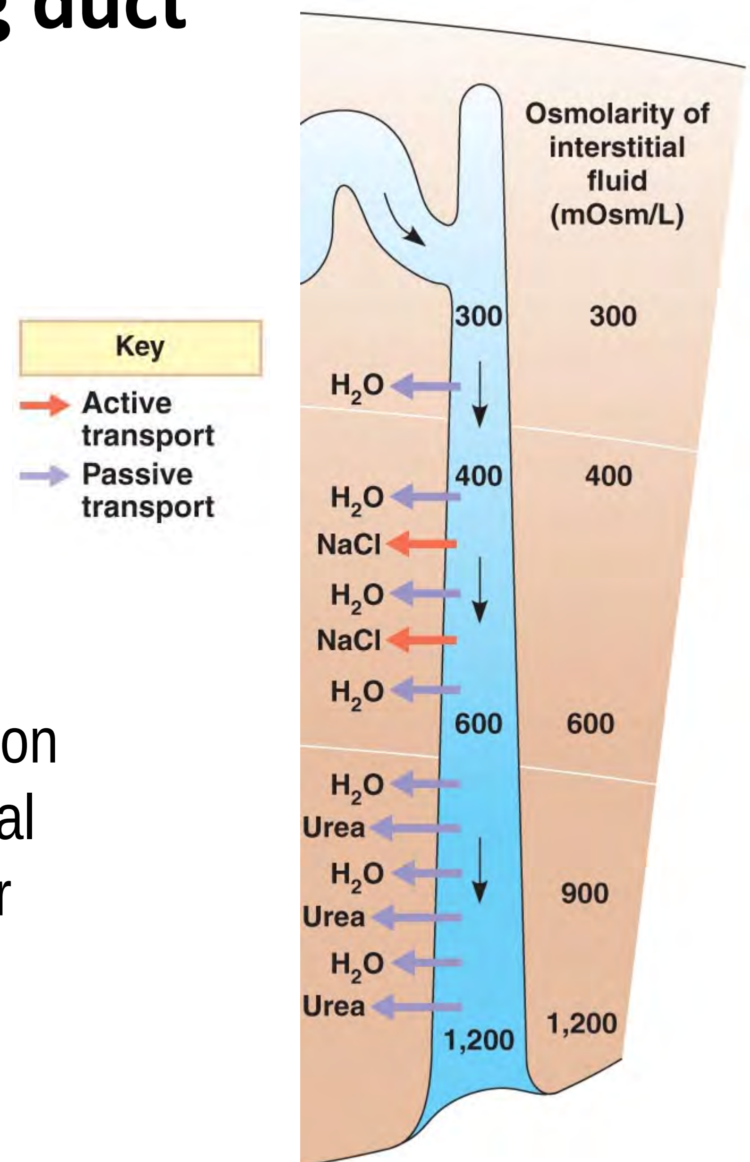


Figure 44.16 (Campbell 9th ed.)

Multiple nephrons drain into a common collecting duct which then carries final urine into ureter and towards bladder

39

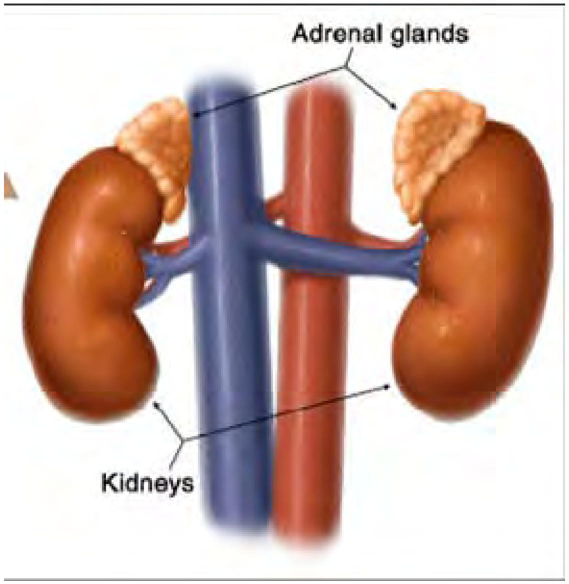
Osmoregulation Controlled

Collecting duct

- Final processing depends on bodies needs
- Regulated by hormones

  A. If H_2O <u>and</u> salt needed by body:

  - Na^+ permeability increased by hormone (aldosterone) from adrenal gland and then H_2O follows (via osmosis)



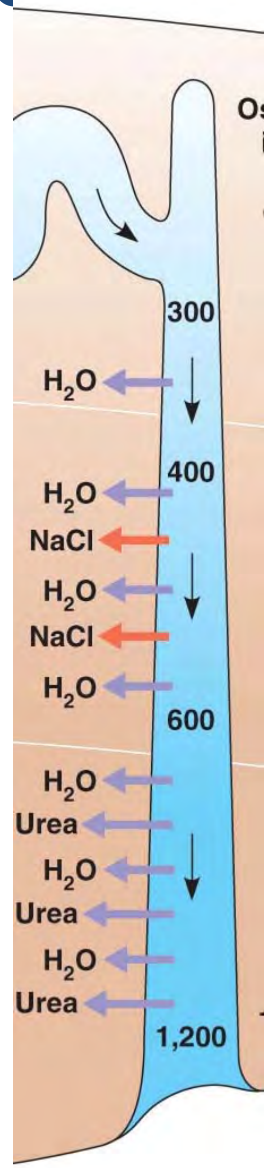


Figure 44.16 (Campbell 9th ed.)

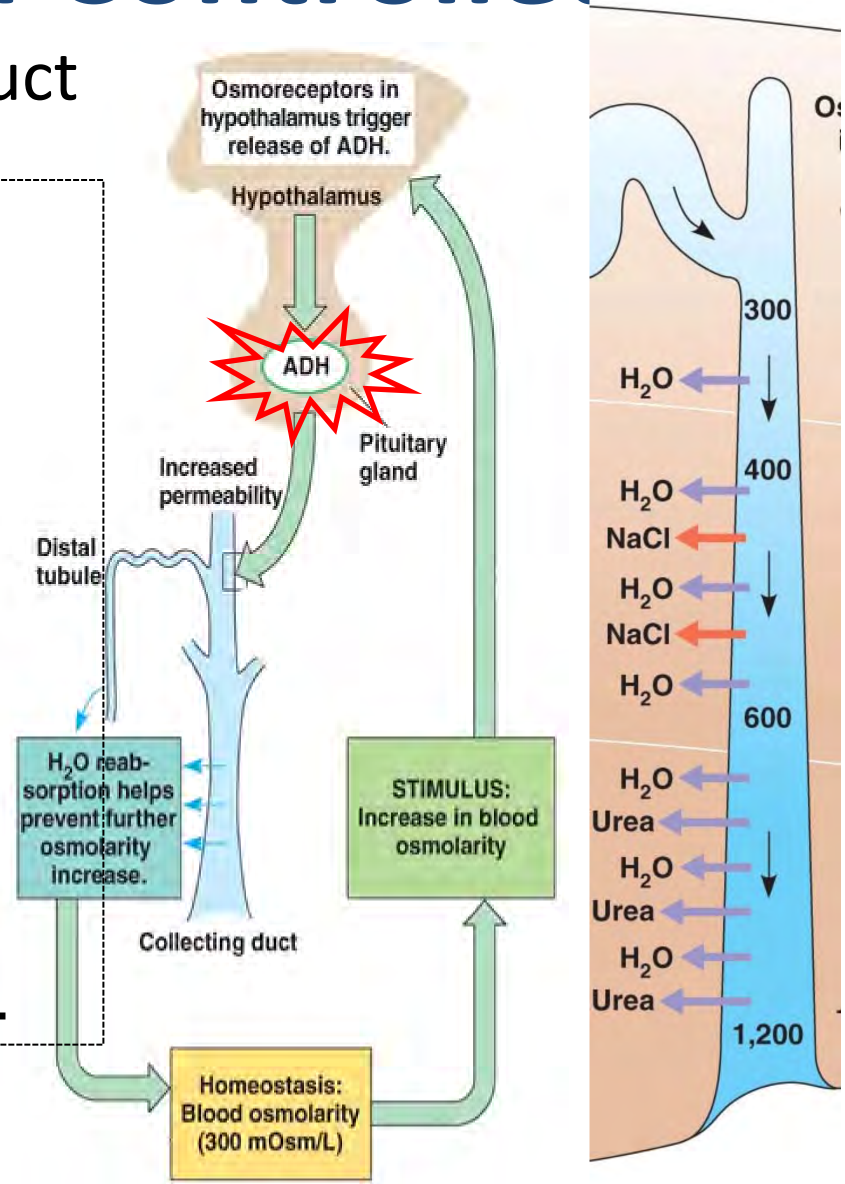
Osmoregulation Controlled

Collecting duct

- Final processing depends on bodies needs
- Regulated by hormones

B. If only H_2O is needed by body:

- H_2O permeability increased by hormone (ADH) from pituitary gland
- If more H_2O reabsorption is needed (but not NaCl), urea can also be moved out of collecting duct to increase [solute] in surrounding tissue.



ADH = Antidiuretic hormone

Figures 44.16 and 44.19 (Campbell 9th ed.)

41

Summary of Filtrate Concentration

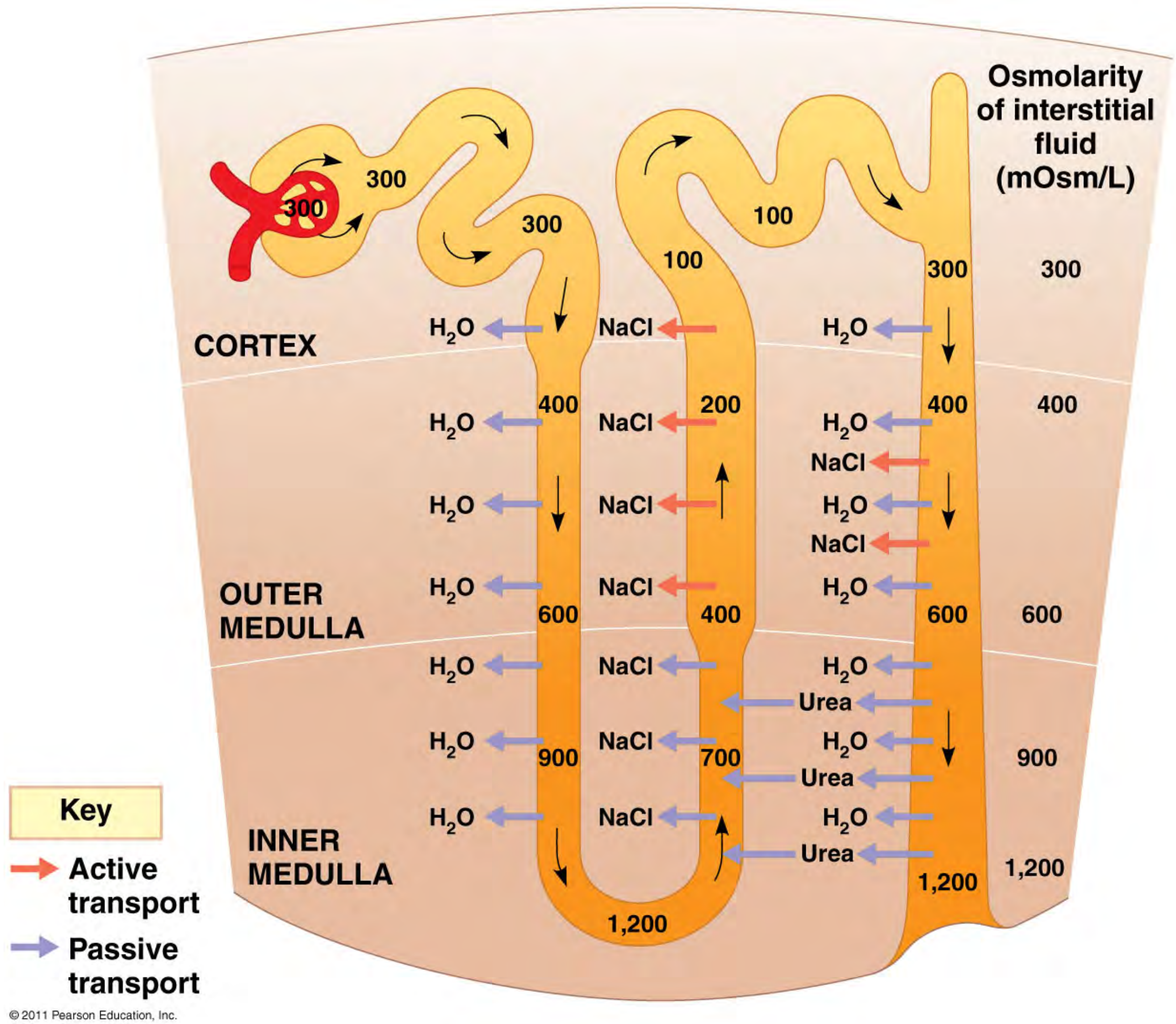
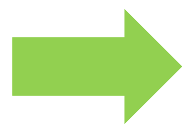


Figure 44.16 (Campbell 9th ed.)

St. Patty's Hangover



Alcohol is a ***diuretic*** – inhibits water reabsorption in the nephrons
(Leads to dehydration, which causes headaches)

44 Readings on which you will NOT be tested

- Animals that live in temporary waters and Figure 44.5 (955-956)
- Figure 44.6 (956)
- Adaptations of the vertebrate kidney in diverse environments (967-968)
- Figures 44.20 and 44.21 and associated text (969-970)
- Renin-Angiotensin and Figure 44.22 (970-971)
- Homeostatic regulation of the kidney (971)

In general:

- You are NOT responsible for definitions of terms or sections included in the text but which were not discussed in lecture
- You are not responsible for the details of examples used in the text but not discussed in lecture. HOWEVER, these additional examples will help your understanding of concepts discussed and may be used on exams to test if you understand the general concepts.
- You ARE responsible for material covered in lecture but not included in the readings

45

Next

- Chapter 45: Endocrine system