Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

Enduring understanding 2.D: Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.

Essential knowledge 2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.

a. Continuity of homeostatic mechanisms reflects common ancestry, while changes may occur in response to different environmental conditions. [See also 1.B.1]

Essential knowledge 2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.

b. Organisms have various mechanisms for obtaining nutrients and eliminating wastes.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

-Gas exchange in aquatic and terrestrial plants

-Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, one-way digestive systems

-Respiratory systems of aquatic and terrestrial animals

-Nitrogenous waste production and elimination in aquatic and terrestrial animals

Digestion

- **DIGESTION- breaking food into particles small enough to be absorbed into cells (increases SA:V)**
  - MECHANICAL DIGESTION-physical breakdown of food, into smaller pieces...increasing surface area
  - CHEMICAL DIGESTION-breakdown of molecules into their subunits
    - this allows passage across membranes
    - and each organism needs to build its own specific molecules

Absorption

- **ABSORPTION- the act of taking up small molecules such as simple sugars and amino acids**

Elimination

- **ELIMINATION- the act of passing undigested material out of the digestive system**

Digestive Compartments

How are animals able to digest molecules that they themselves are made of?

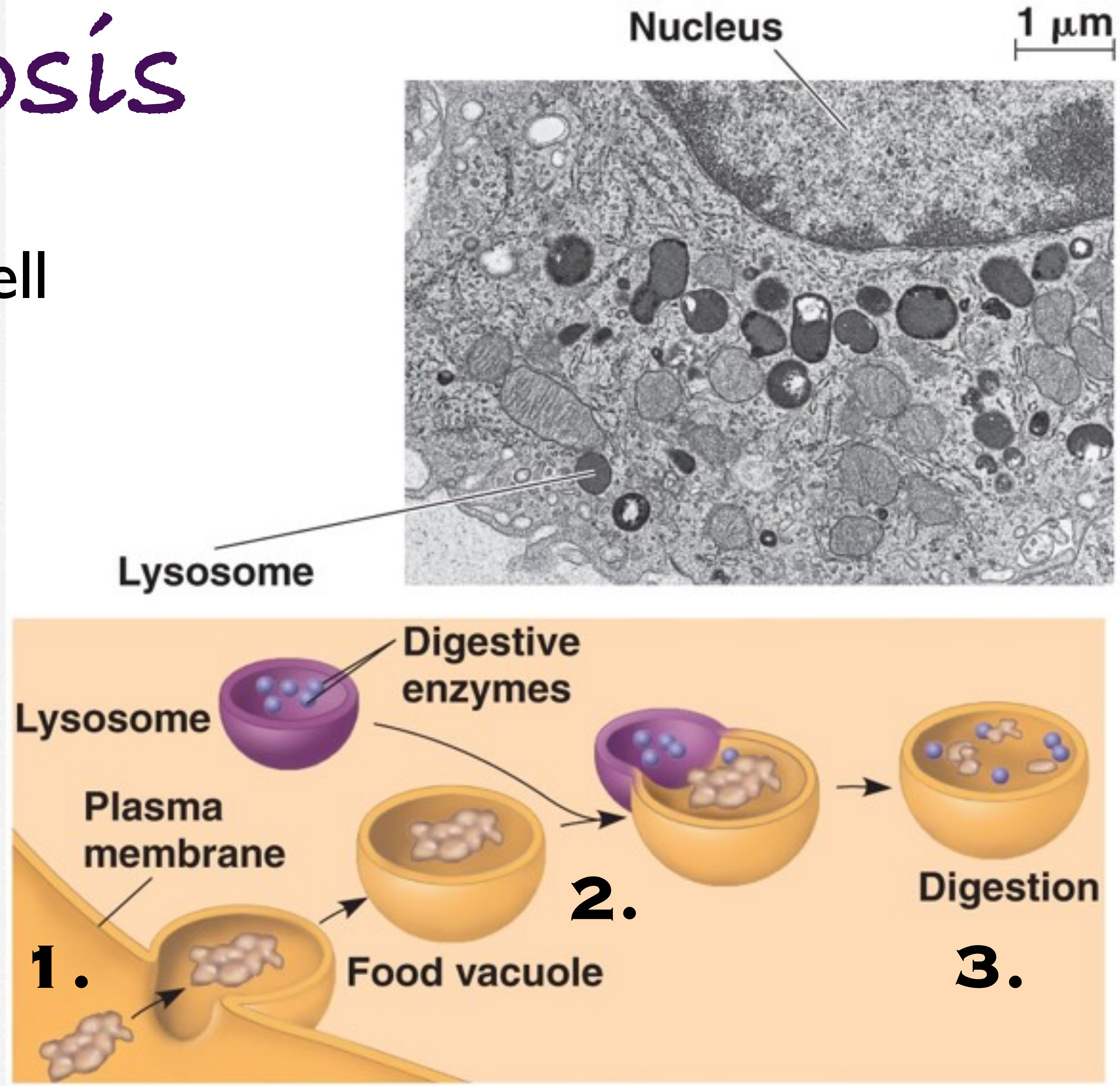
- The evolutionary adaptation found across a wide range of organisms is the processing of food within specialized compartments.
    - These compartments can be intracellular (vacuoles) or extracellular (digestive organs)

Intracellular Compartments

- **Food Vacuoles**- cellular organelles in which enzymes break down food (simplest digestive compartments).
  - Cell engulfs food by **phagocytosis**
  - Food vacuole fuses with **lysosome** (digestive sac)
  - Digestion occurs safely inside compartment
- Few animals digest food exclusively this way, the sponge however is one organism that does.

Phagocytosis

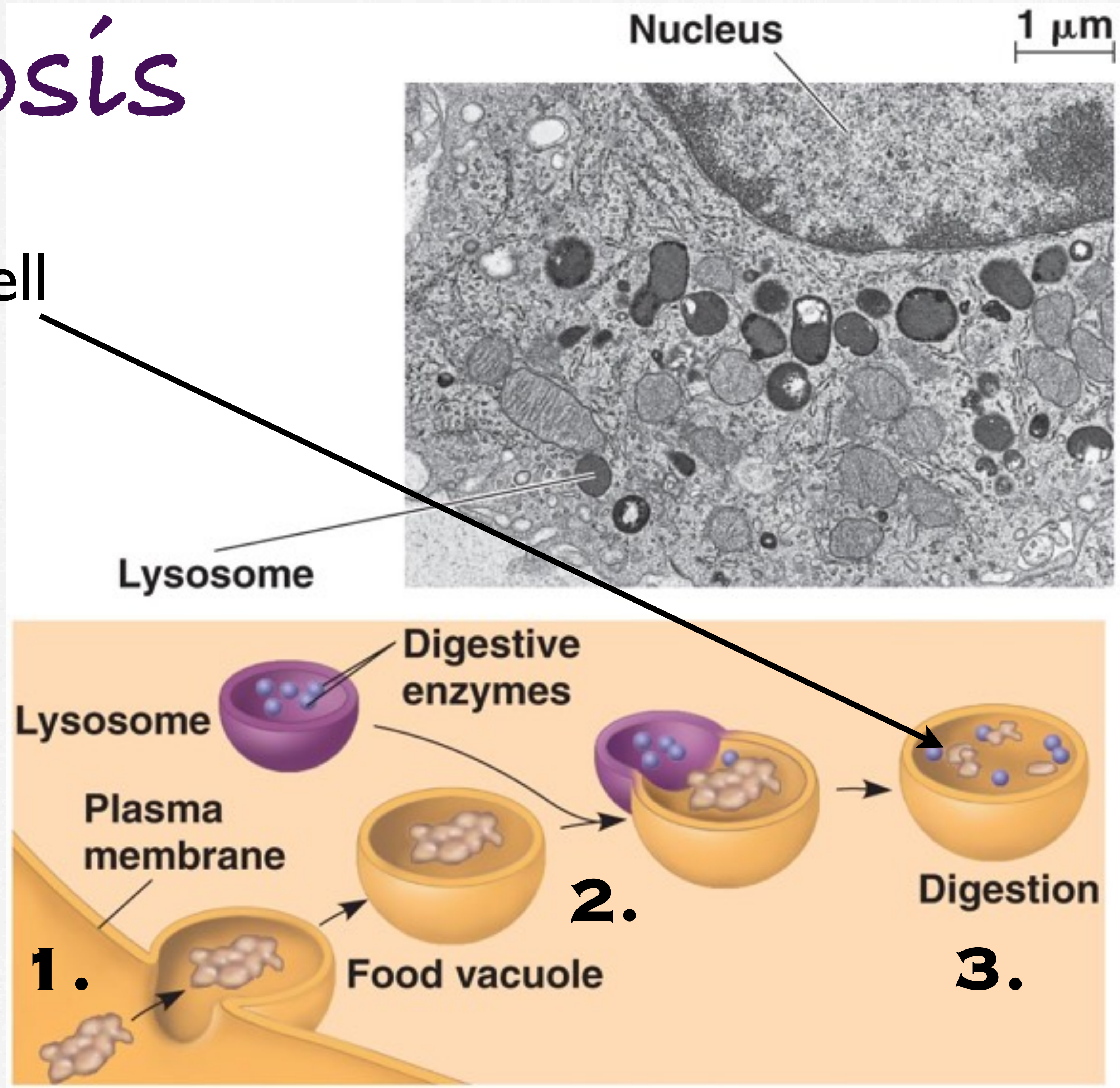
Now nutrients for cell



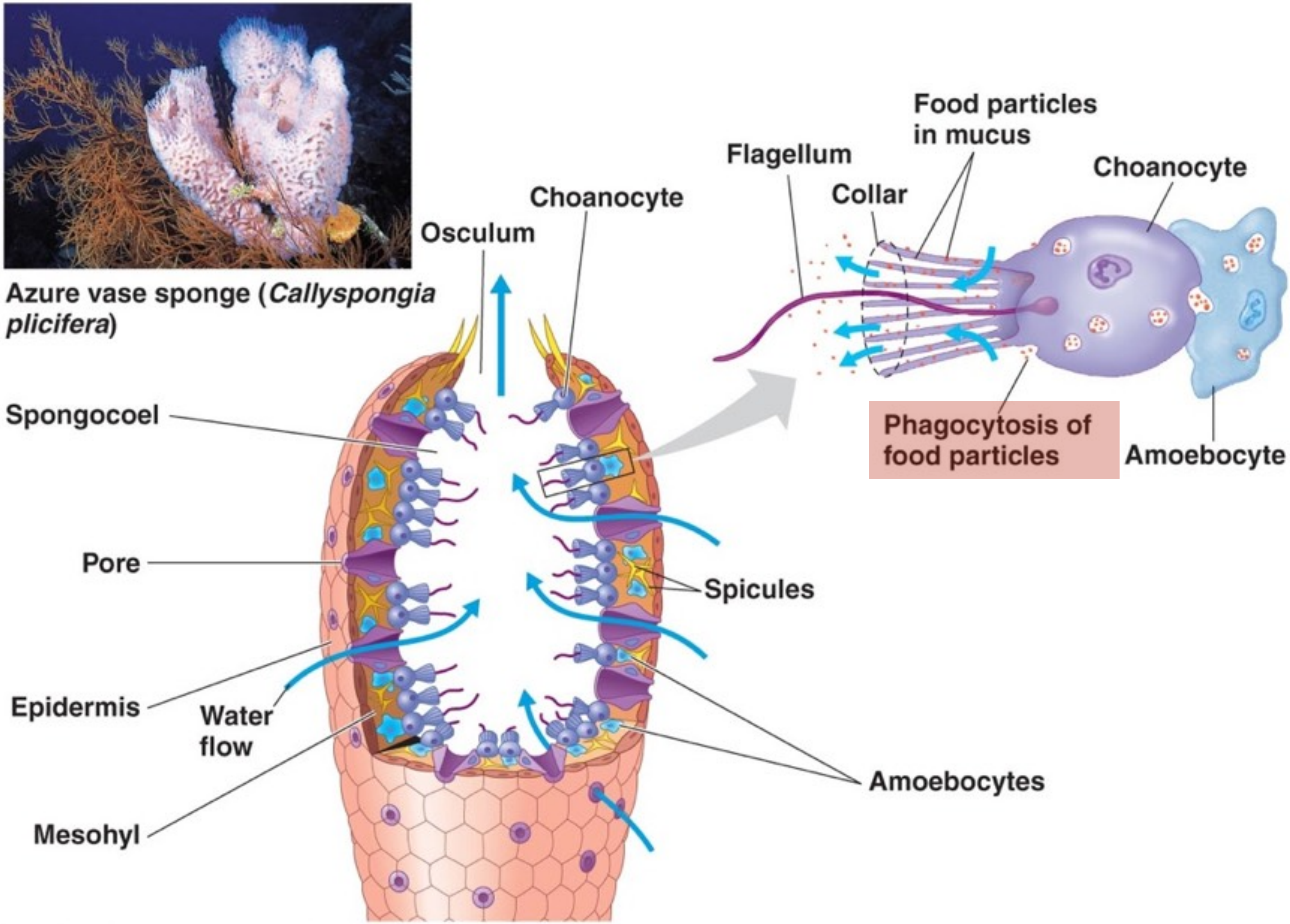
(a) Phagocytosis

Phagocytosis

Now nutrients for cell



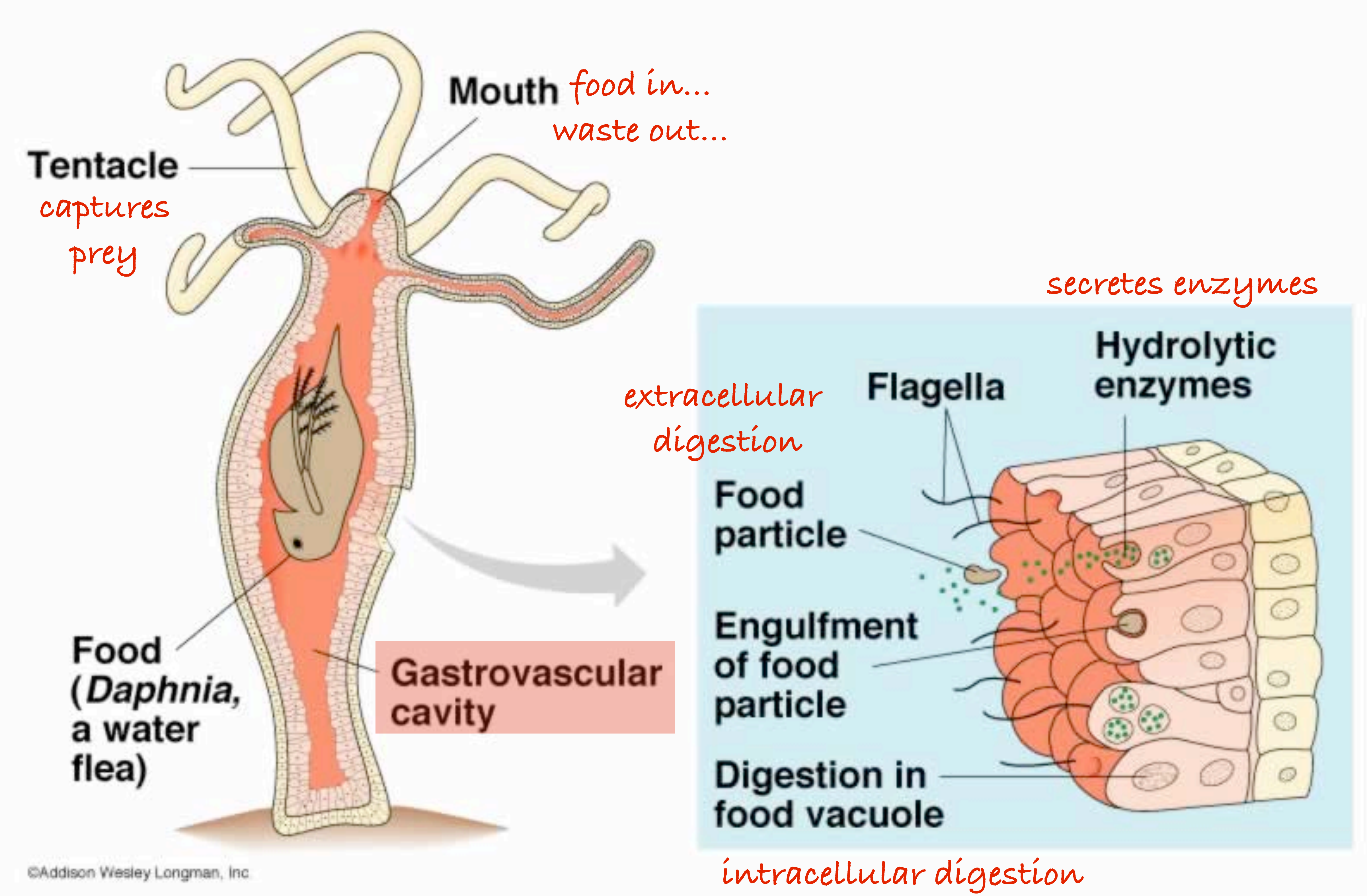
(a) Phagocytosis

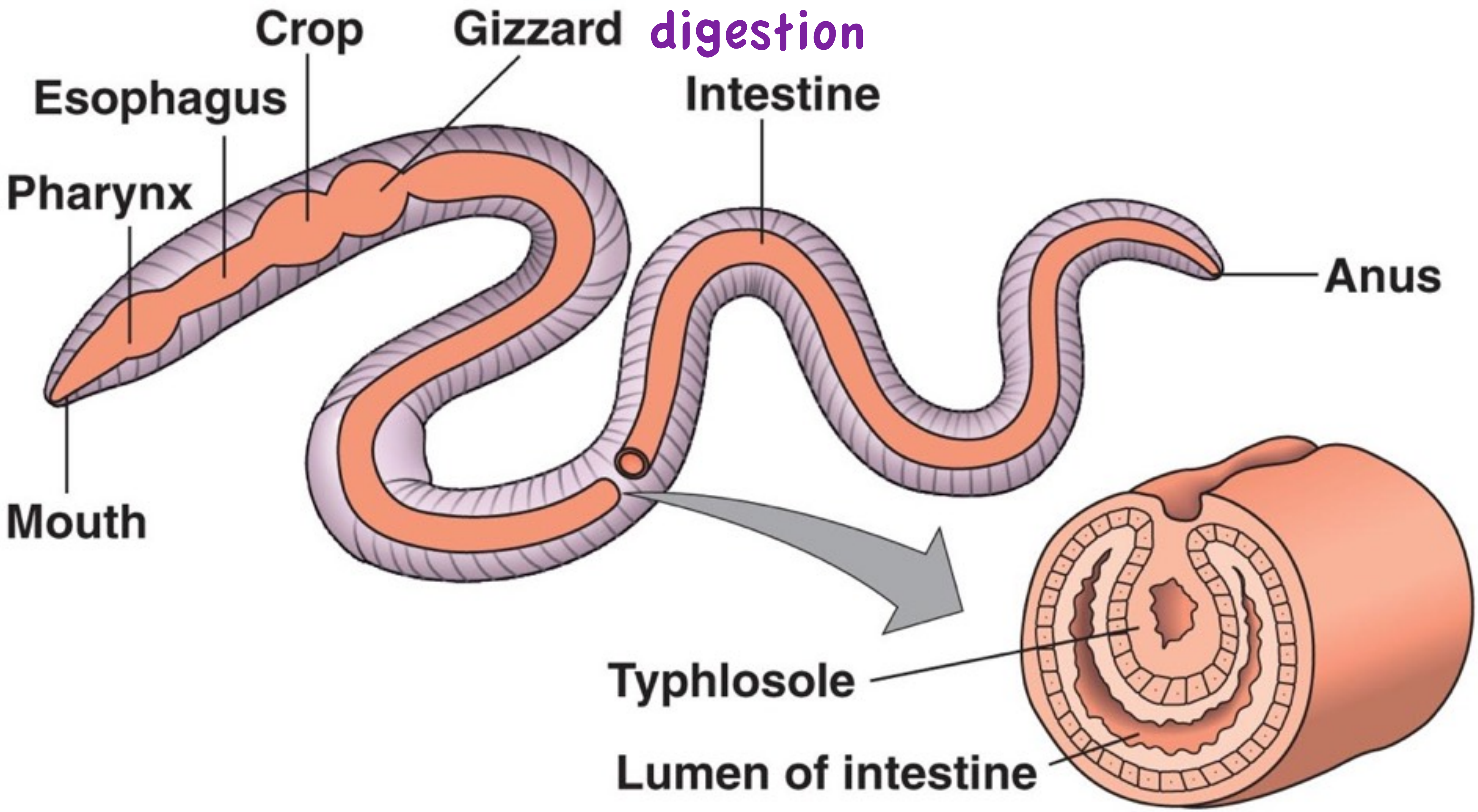


Azure vase sponge (*Callyspongia plicifera*)

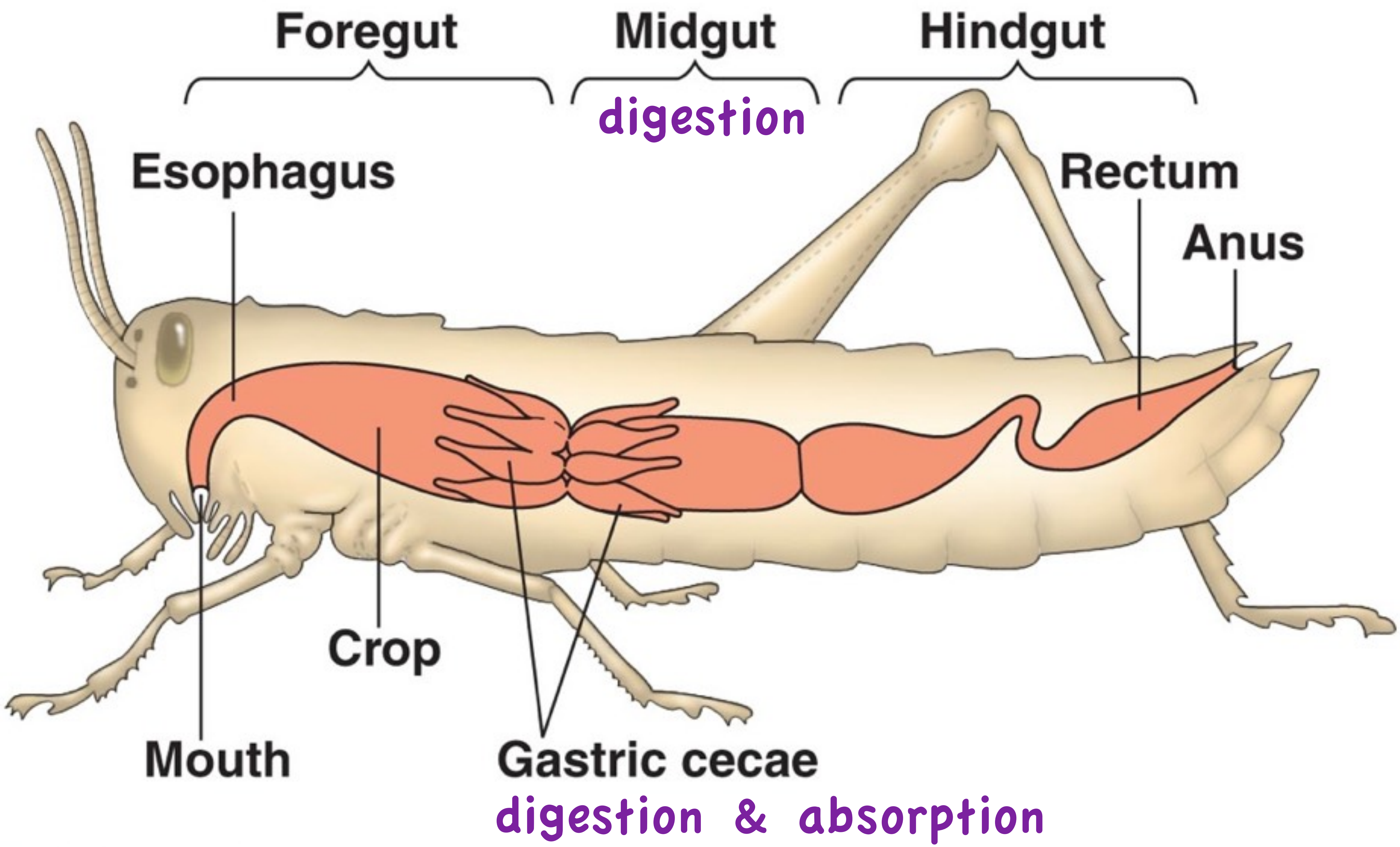
Extracellular Compartments

- Most animal species, molecular breakdown occurs by extracellular digestion, in compartments that continuous with outside of the animal's body.
- Some animals with simple body plans have digestive compartments with a single opening
  - ex. Hydra
- Most animals have a digestive tube extending between two openings: mouth and anus.
  - This tube is called **ALIMENTARY CANAL**

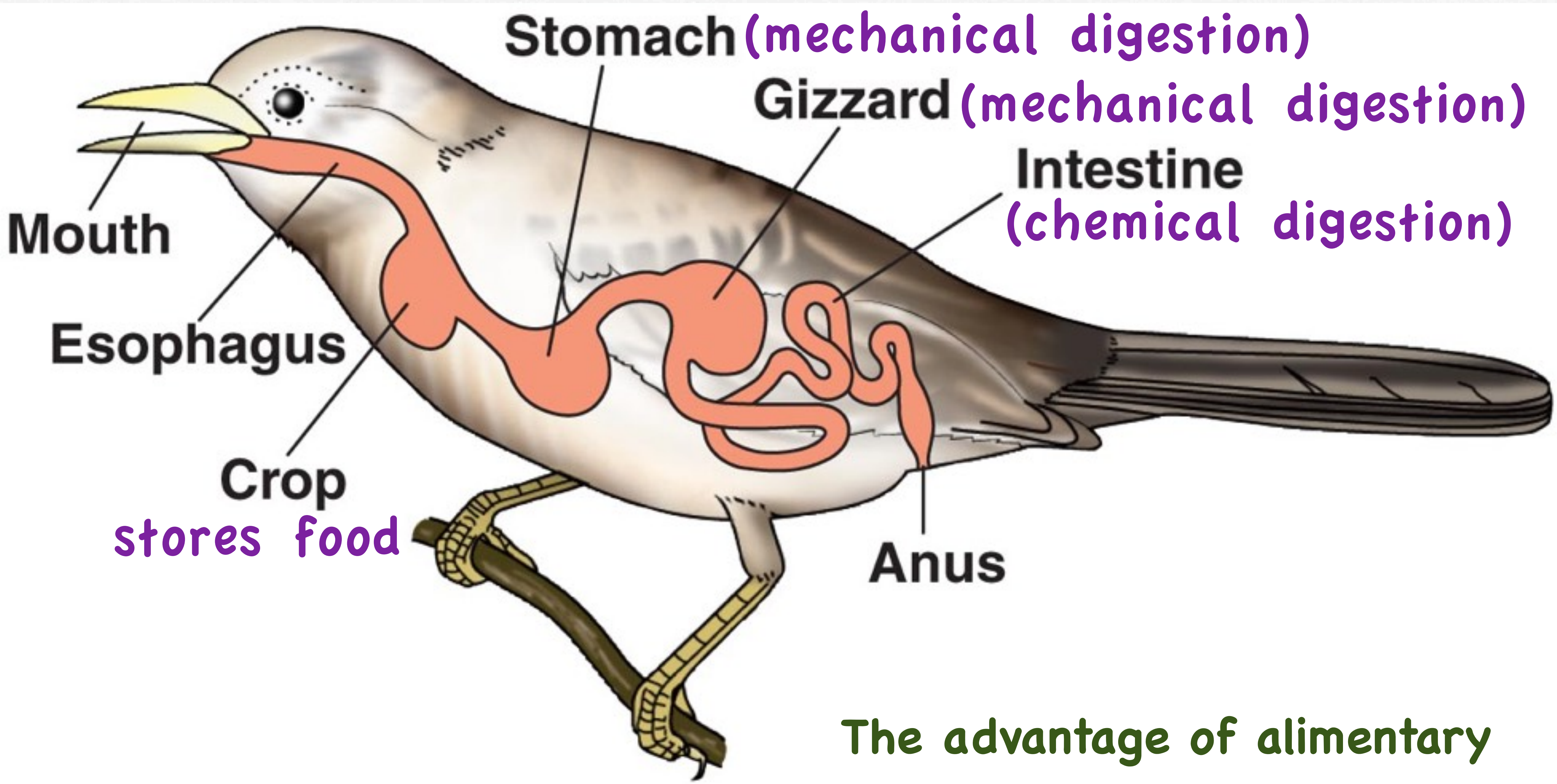

Mouth
food in...
waste out...
Tentacle
captures prey
Food (*Daphnia*, a water flea)
Gastrovascular cavity
secretes enzymes
extracellular digestion
Flagella
Hydrolytic enzymes
Food particle
Engulfment of food particle
Digestion in food vacuole
intracellular digestion
©Addison Wesley Longman, Inc


Crop
Gizzard
digestion
Esophagus
Intestine
Pharynx
Anus
Mouth
Typhlosole
Lumen of intestine

(a) Earthworm



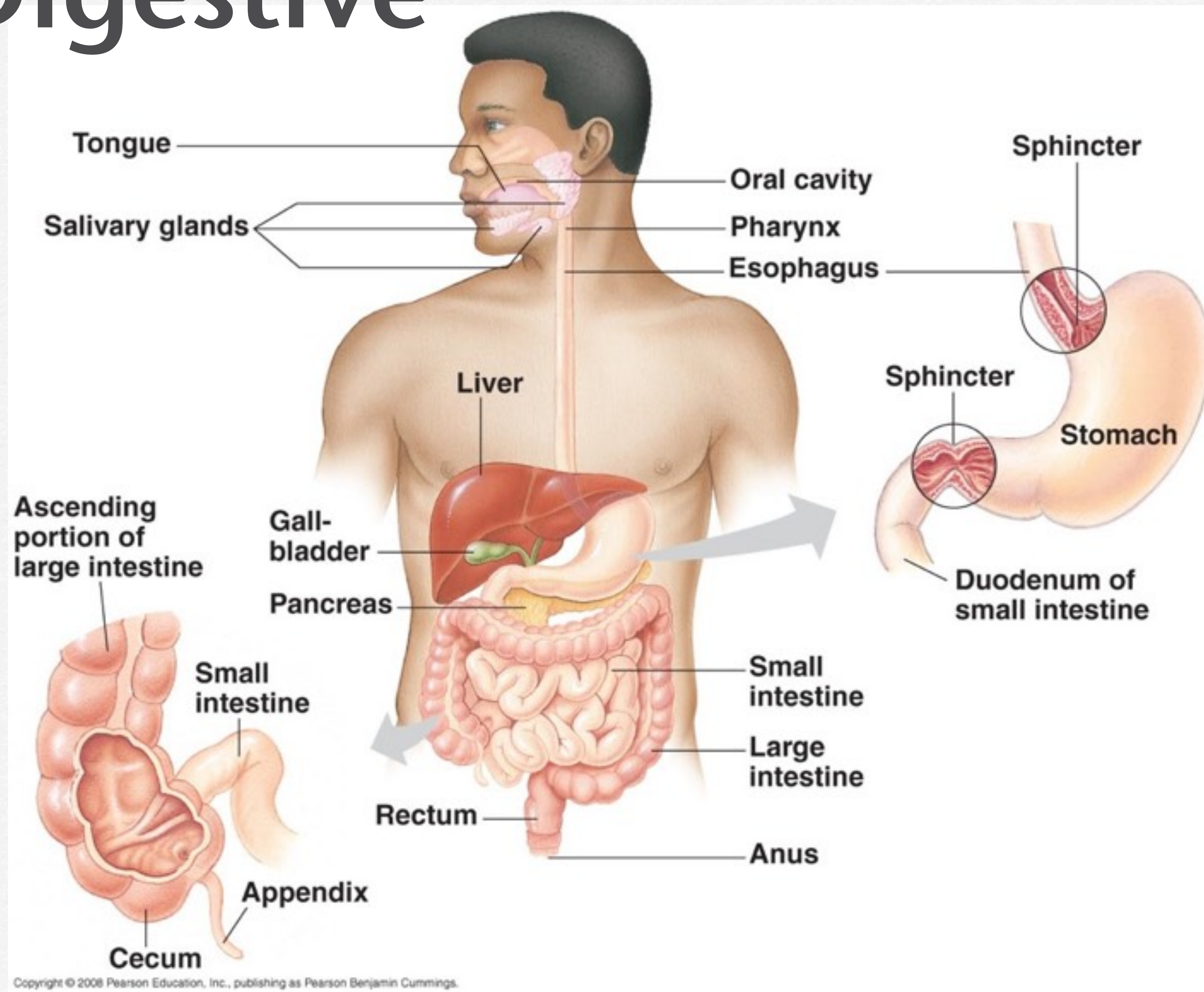
(b) Grasshopper



(c) Bird

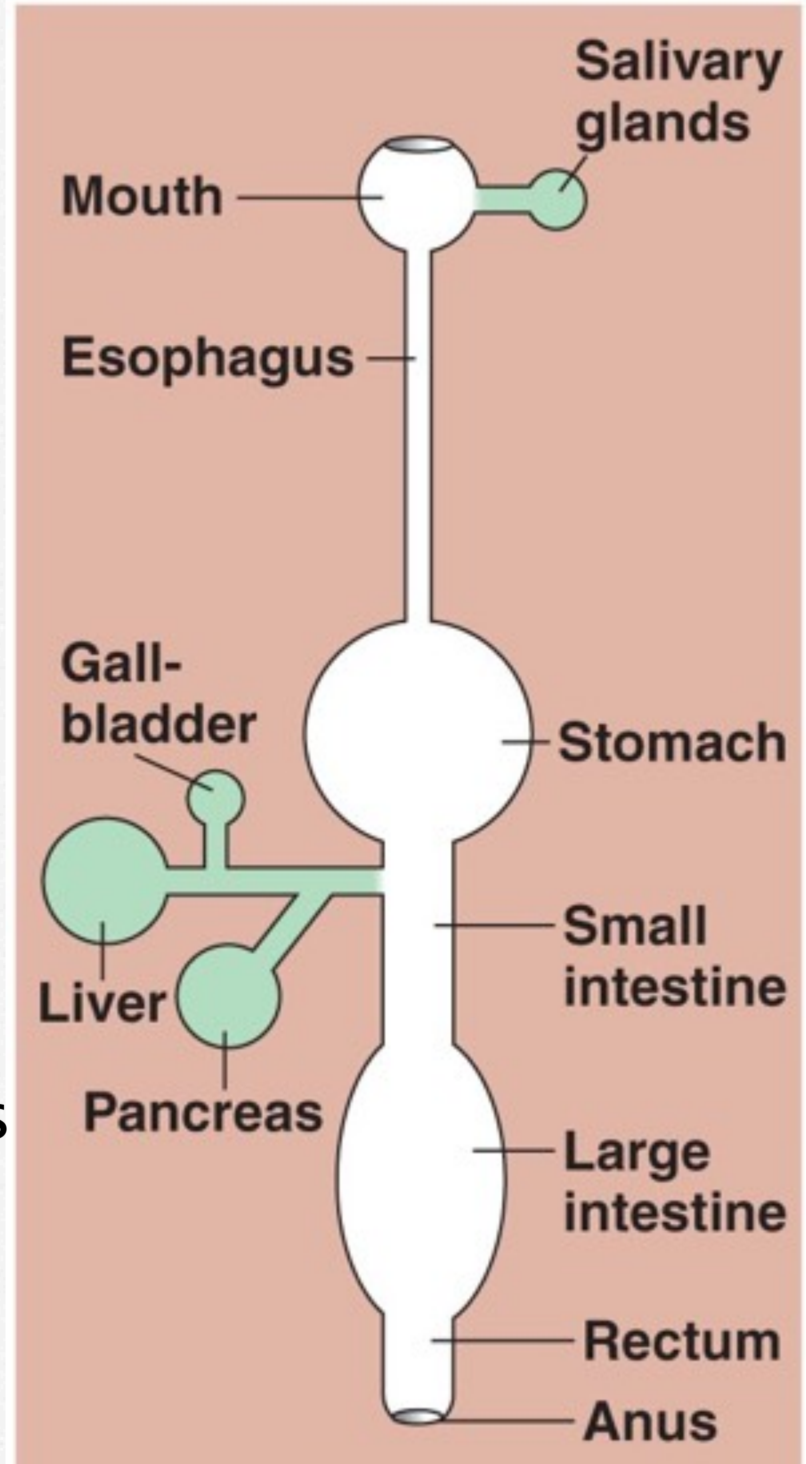
The advantage of alimentary canals is specialization and food can be digested while an earlier meal is being absorbed

HumanDigestive System



starts chemical digestion

mechanical digestion



A schematic diagram of the human digestive system

stores bile

food storage
mechanical digestion

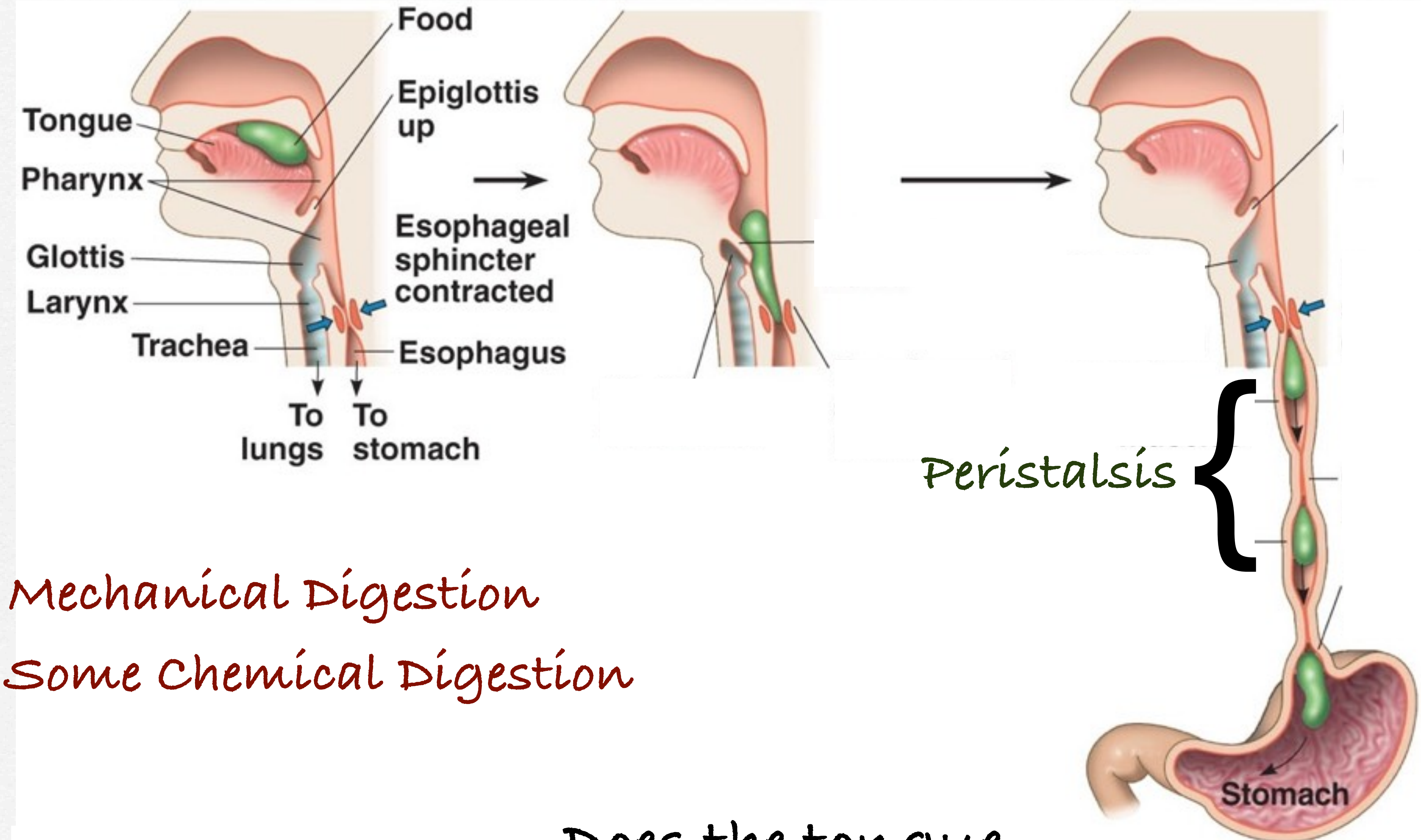
makes bile
detoxifies

chemical digestion
absorption

digestive enzymes

absorption

waste storage



Mechanical Digestion

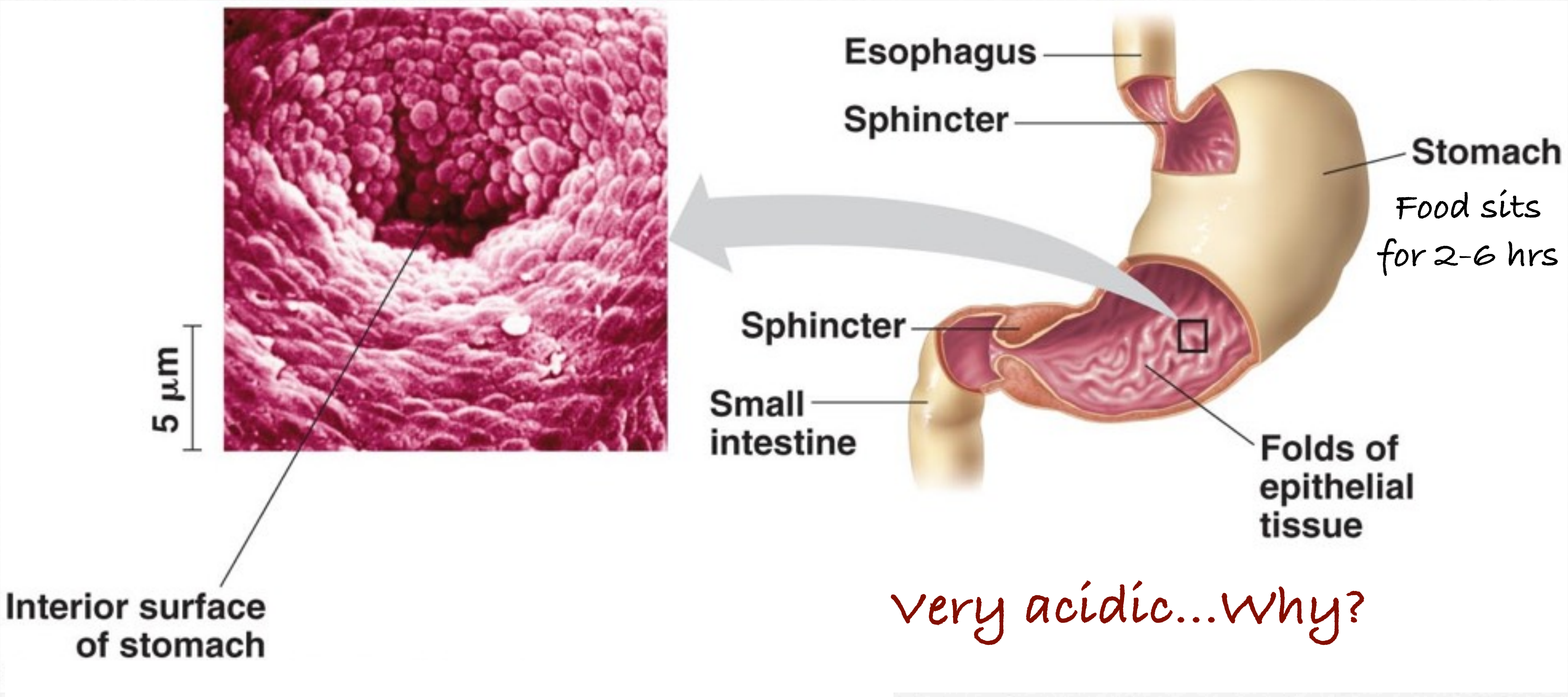
Some Chemical Digestion

Does the tongue have any function?

Mainly Storage

Chemical Digestion

Some Mechanical Digestion

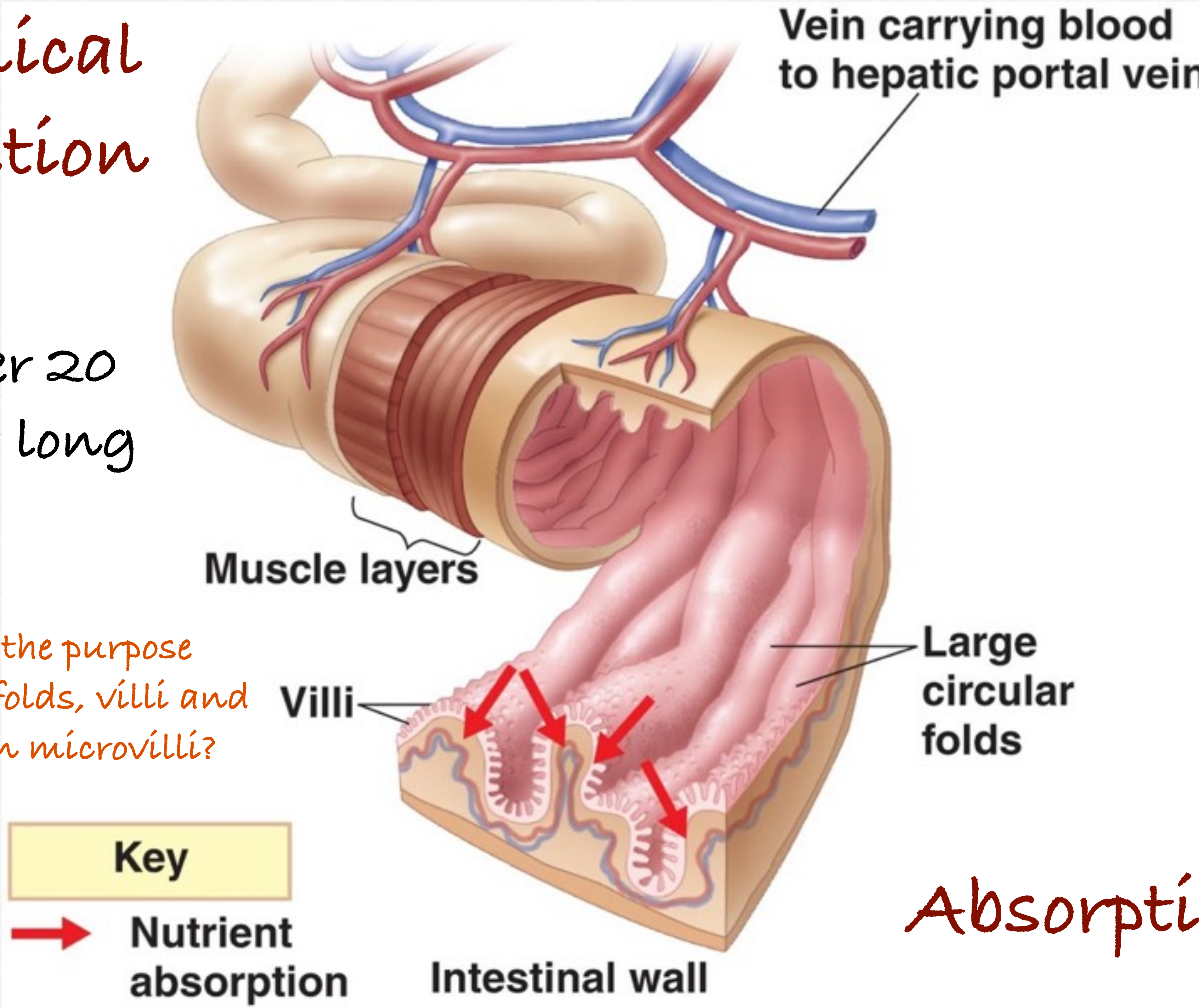


Very acidic...Why?

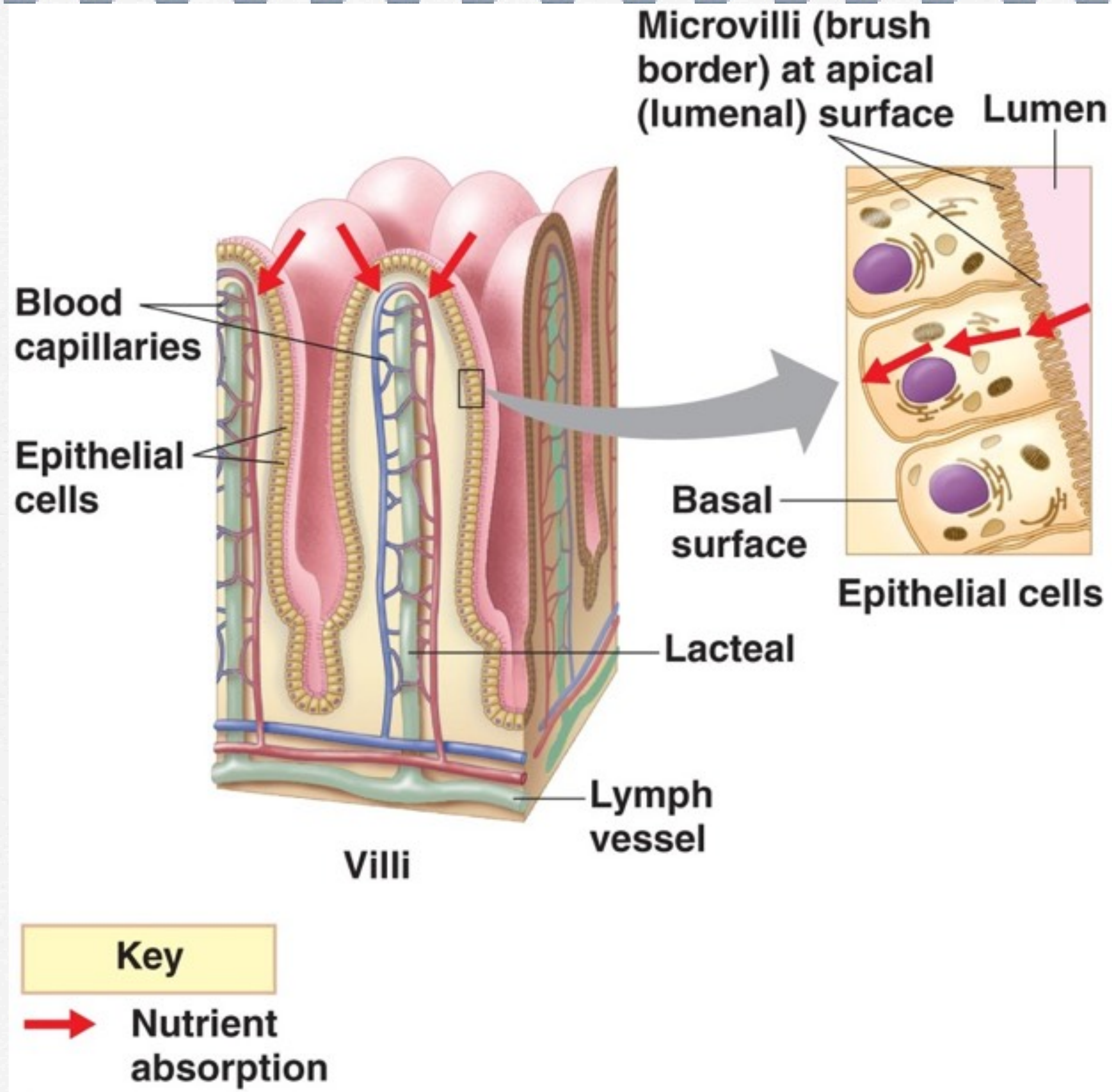
Chemical Digestion

over 20 feet long

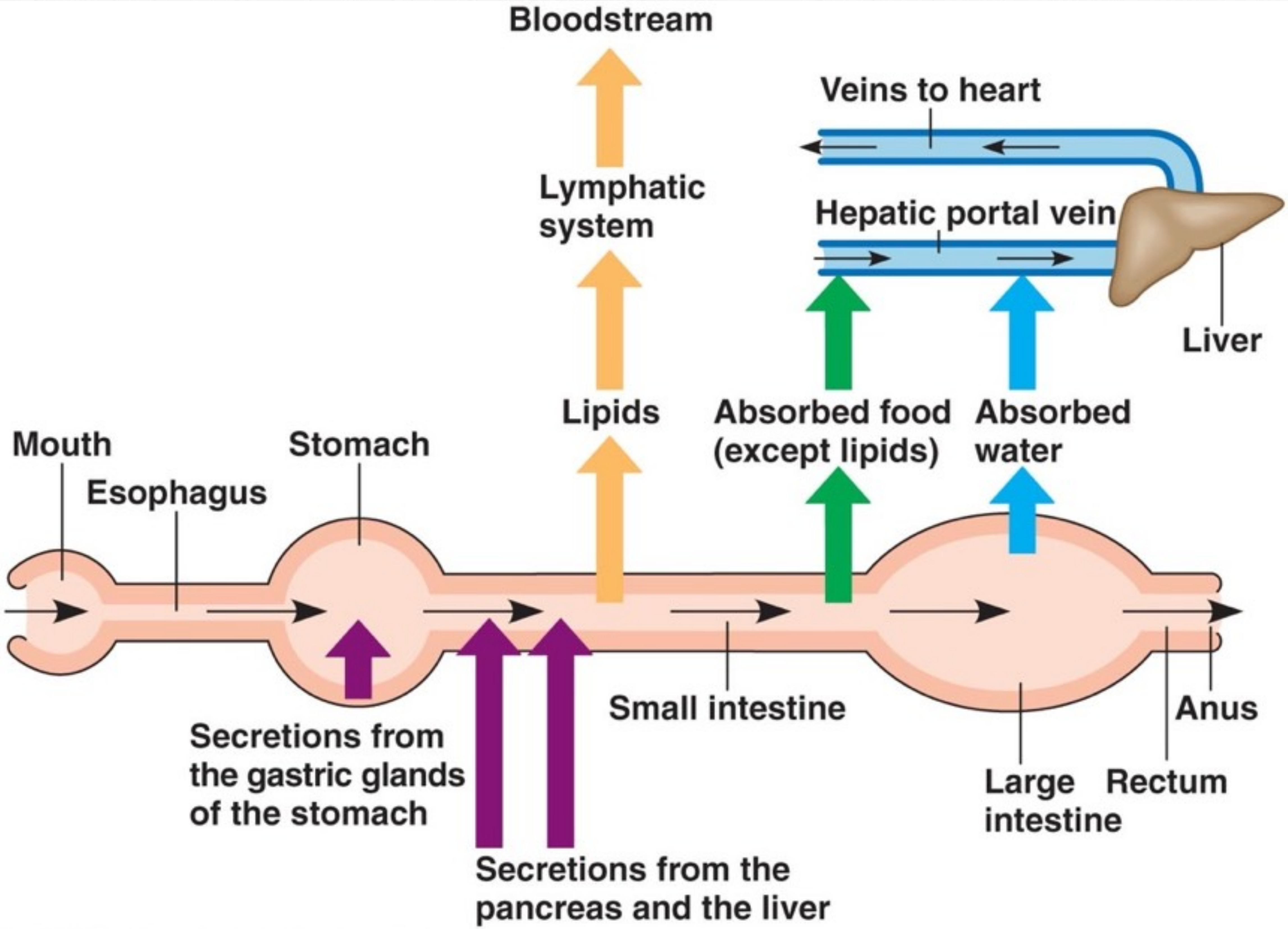
What is the purpose behind the folds, villi and the unseen microvilli?



Absorption



The absorption can be active or passive depending the nutrient


Bloodstream
Veins to heart
Lymphatic system
Hepatic portal vein
Liver
Lipids
Absorbed food (except lipids)
Absorbed water
Mouth
Stomach
Esophagus
Small intestine
Anus
Secretions from the gastric glands of the stomach
Large intestine
Rectum
Secretions from the pancreas and the liver

Essential knowledge 2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.

c. Homeostatic control systems in species of microbes, plants and animals support common ancestry. [See also 1.B.1]

To foster student understanding of this concept, instructors can choose an illustrative example such as:

Excretory systems in flatworms, earthworms and vertebrates

Osmoregulation in bacteria, fish and protists

Osmoregulation in aquatic and terrestrial plants

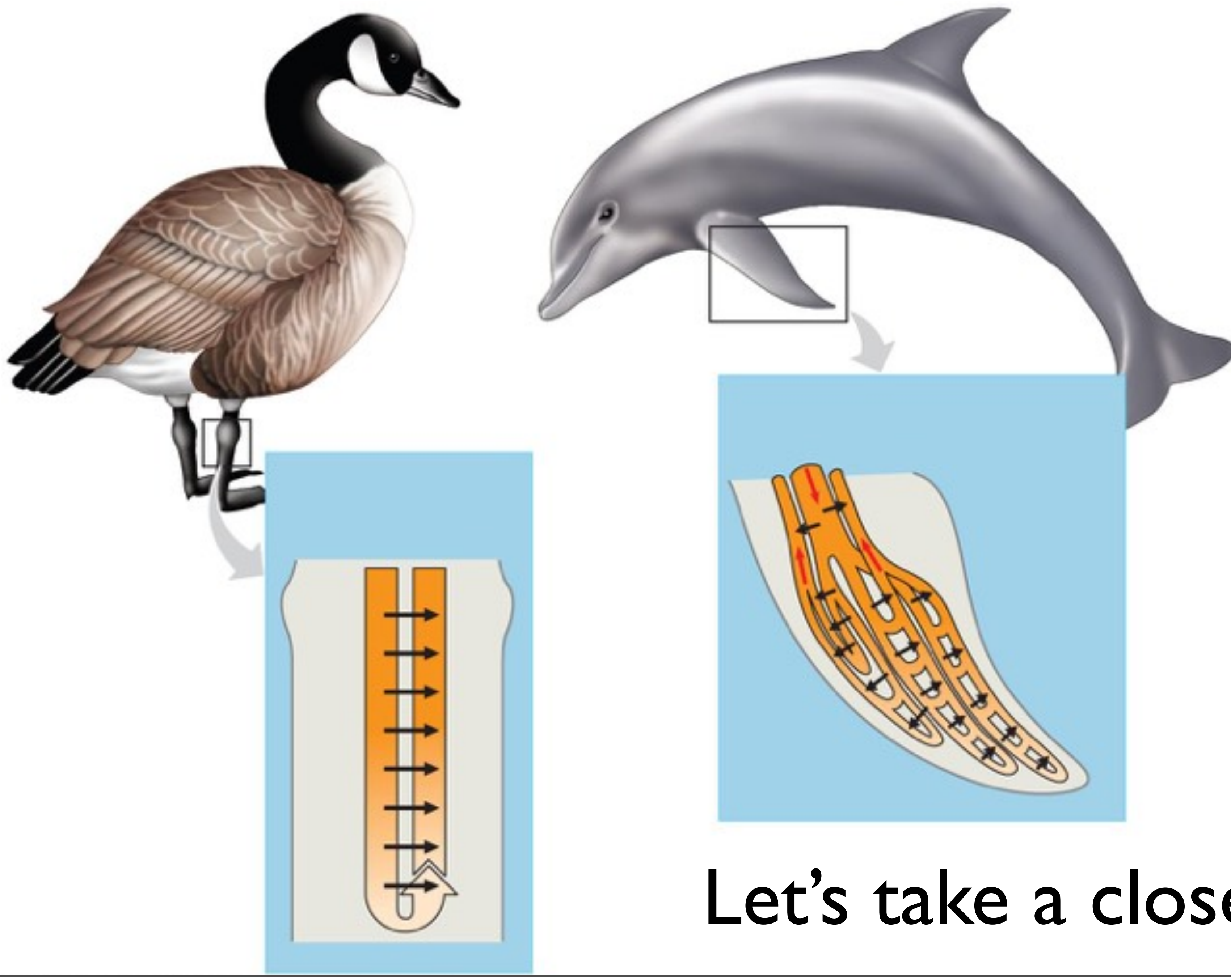
Circulatory systems in fish, amphibians and mammals

Thermoregulation in aquatic and terrestrial animals (countercurrent exchange mechanisms)

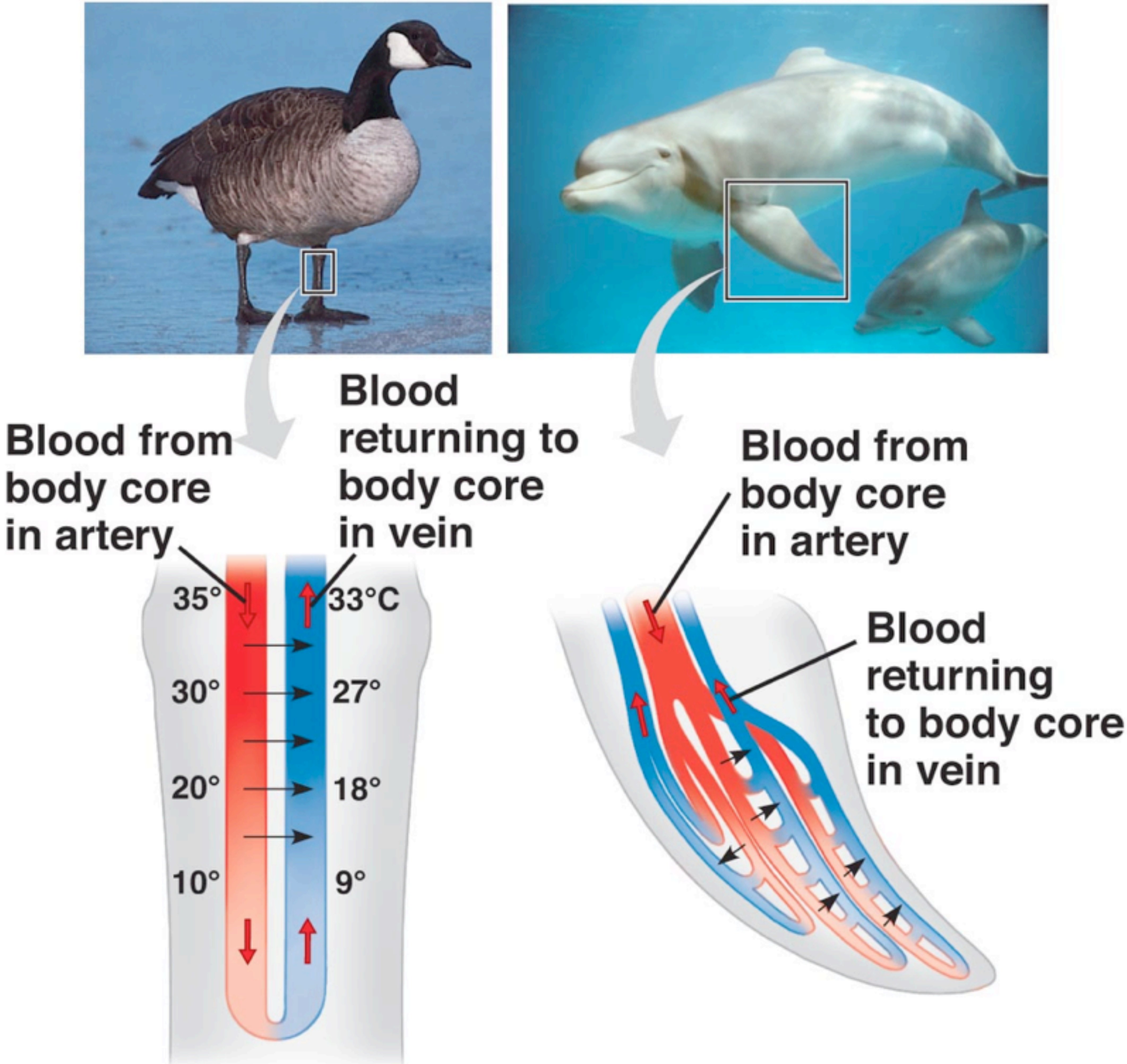
Thermoregulation

Circulatory Adaptations

- Another circulatory adaptation relies on a ***Countercurrent Exchange,*** the transfer of heat (or solutes) between fluids that are flowing in opposite directions



Let's take a closer look...


Blood from body core in artery
Blood returning to body core in vein
35°
33°C
30°
27°
20°
18°
10°
9°
Blood from body core in artery
Blood returning to body core in vein

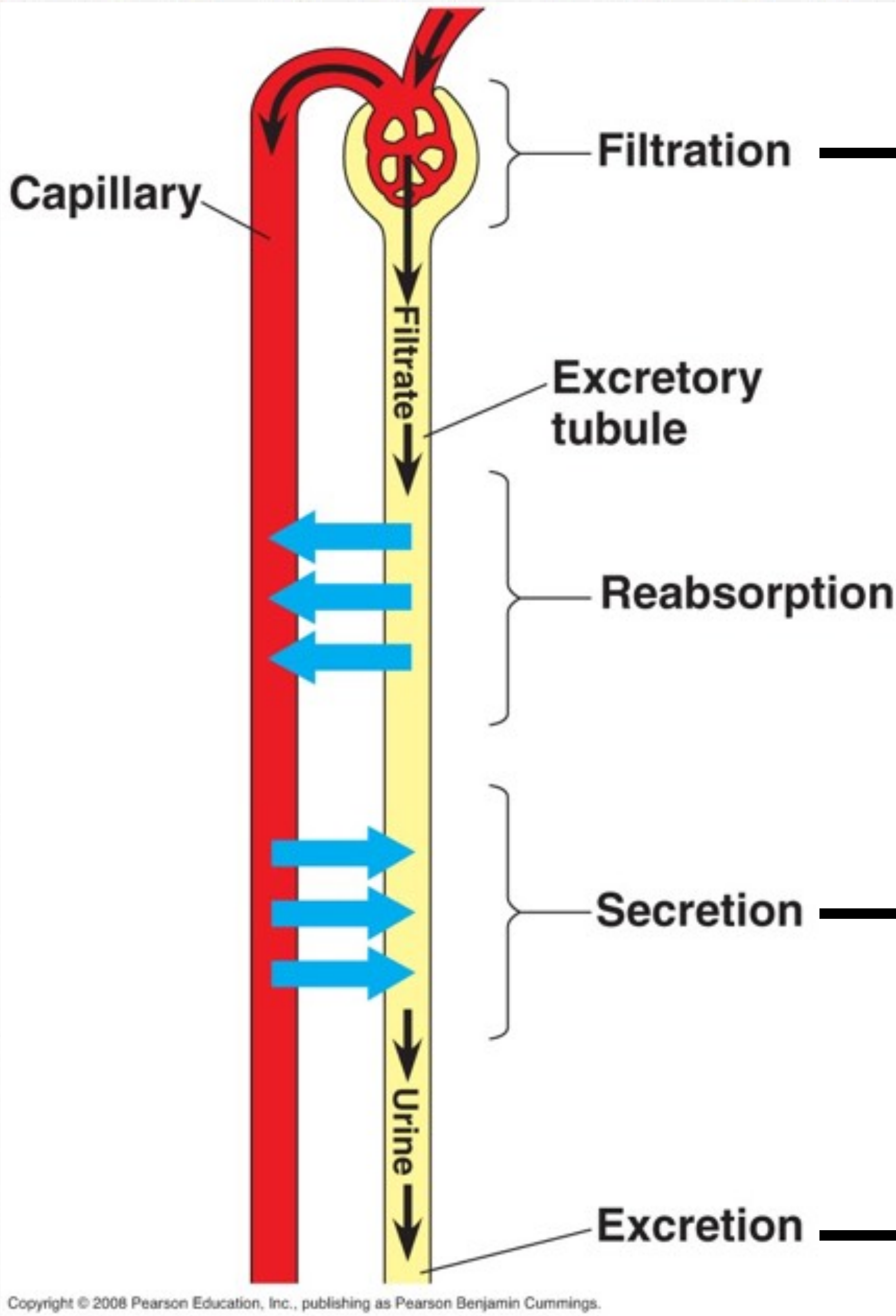
Excretory Systems

Excretory Systems

- ALL water balance relies on the regulation of solute movement between internal fluids and external environments.
- Most of this movement in multicellular organisms is handled by excretory systems.
- These systems not balance water and solute concentrations but also excrete harmful wastes.

Excretion: The Process

- Animals produce a fluid waste called urine through 4 basic steps:
  - Filtration
  - Reabsorption
  - Secretion
  - Excretion

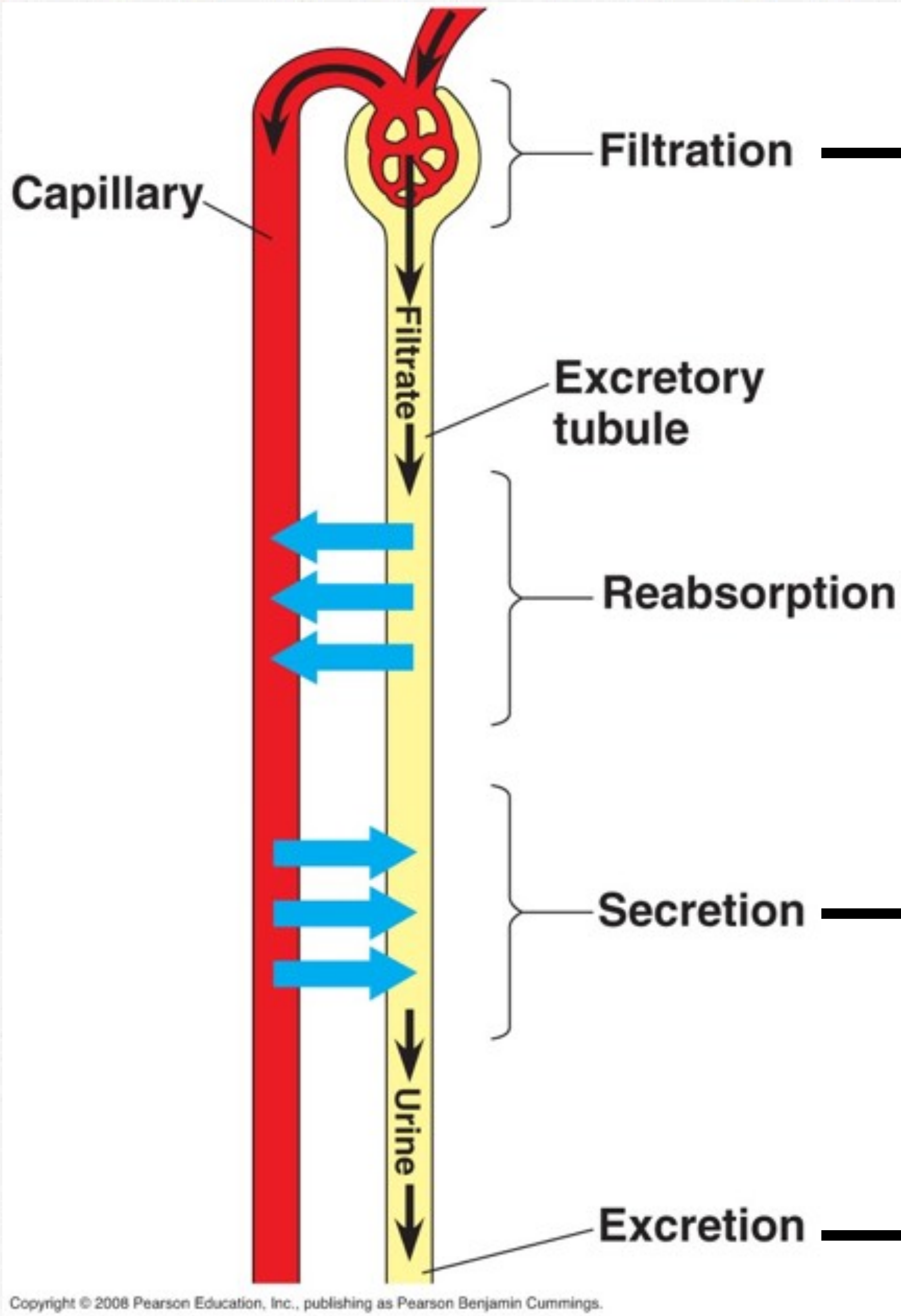


Water and solutes are forced out of the blood

Reclaims valuable substances from filtrate

Excessive solutes and toxins are removed from the blood

The altered filtrate leaves body as urine



Filtration → water, salts, sugars, amino acids, nitrogenous waste, etc

Reabsorption → water, certain salts, glucose, amino acids, vitamins, hormones

Secretion → additional solutes and waste

Excretion → water and nitrogenous waste, etc

Diverse Excretory Systems

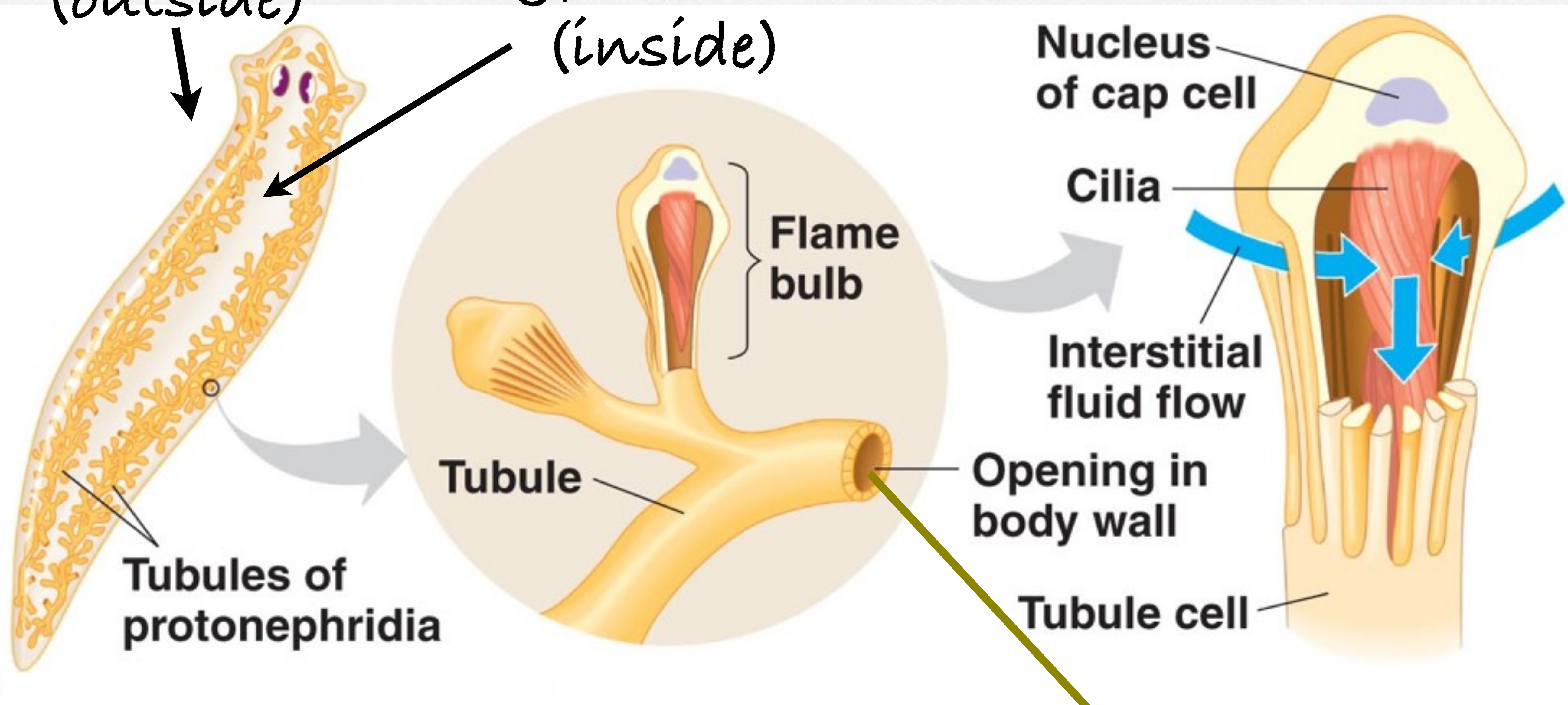
- Although structures vary among animals the functions remain the same-control solute concentration and balance water uptake and output.
  - Protonephridia-flatworms
  - Metanephridia-earthworms
  - Malphigian Tubules-insects (grasshoppers)
  - Kidneys-vertebrates (humans)

Protonephridia

- **SERVE TO REGULATE WATER!**
- Waste removal occurs across the body surface or waste is moved into the gastrovascular cavity where leaves through the mouth
- Freshwater flatworms produce dilute urine to counteract the constant influx of water

Hypoosmotic (outside)

Hyperosmotic (inside)

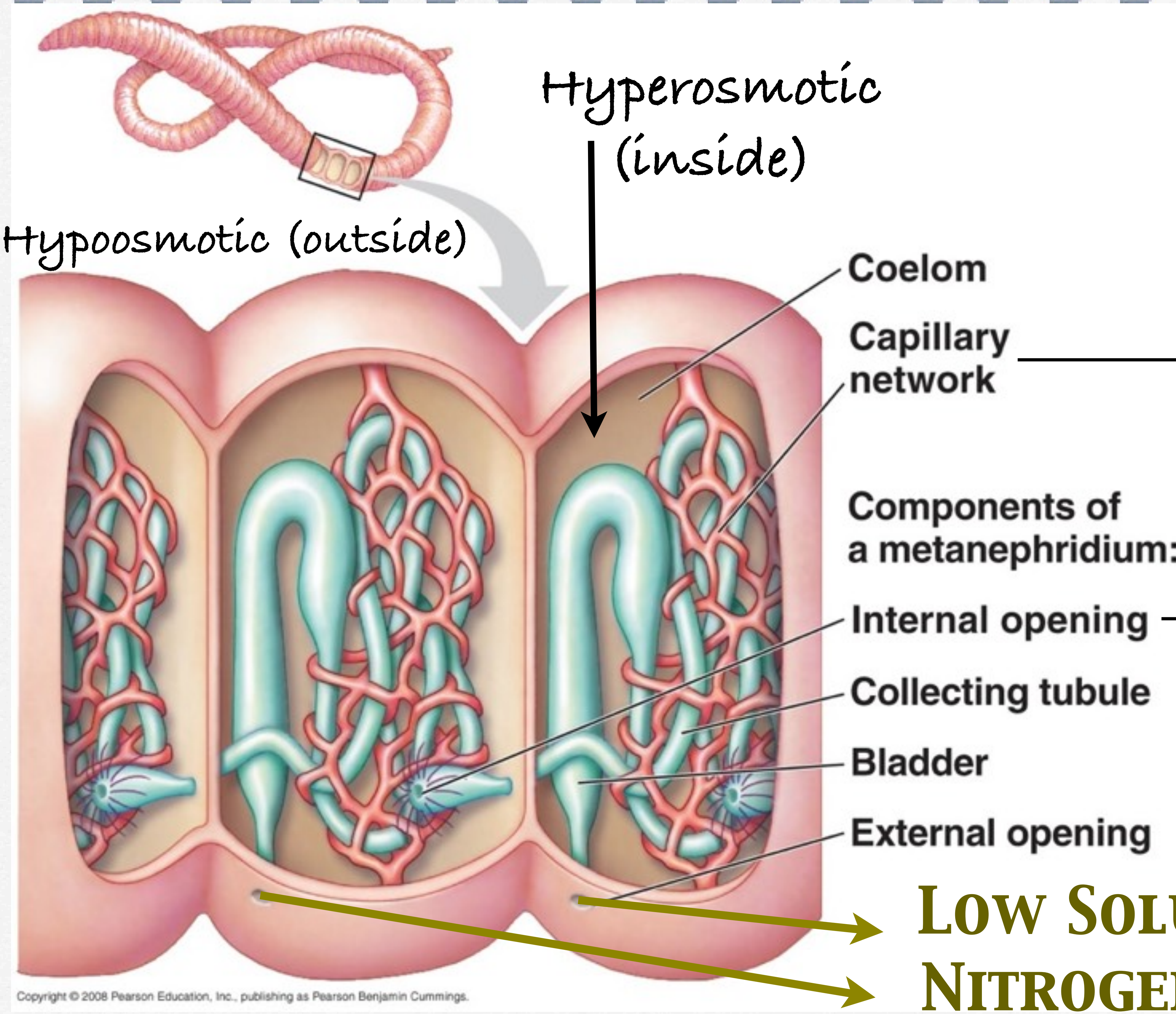


This system is used for osmoregulation, not waste removal

Low Solute Urine

Metanephridia

- **Serve to regulate water and eliminate waste!**
- Waste moves into and remains in the collecting tubule and is eventually excreted to the outside
- Earthworms inhabit moist soils and thus produce dilute urine to counteract the constant influx of water



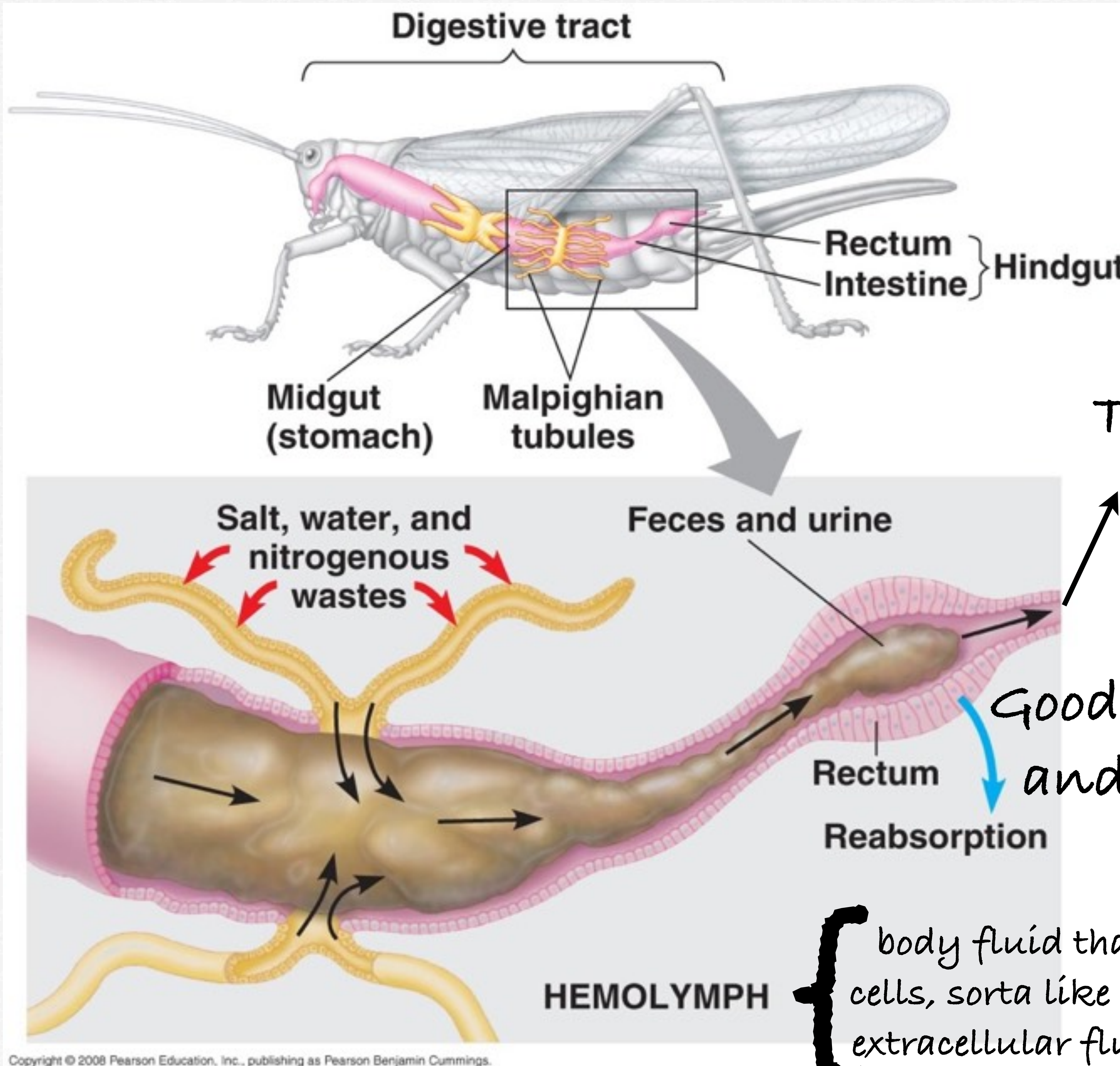
Reabsorbs most solutes ("good ones")

Collects fluid from coelom

Low Solute Urine & Nitrogenous waste

Malpighian Tubules

- **Serve to regulate water and eliminate waste!**
- Nitrogenous waste is actually moved into the (gastrovascular cavity) rectum where it is eliminated along with the feces
- Insects live in hyperosmotic environments and must therefore conserve water, producing non-soluble nitrogenous waste saves water



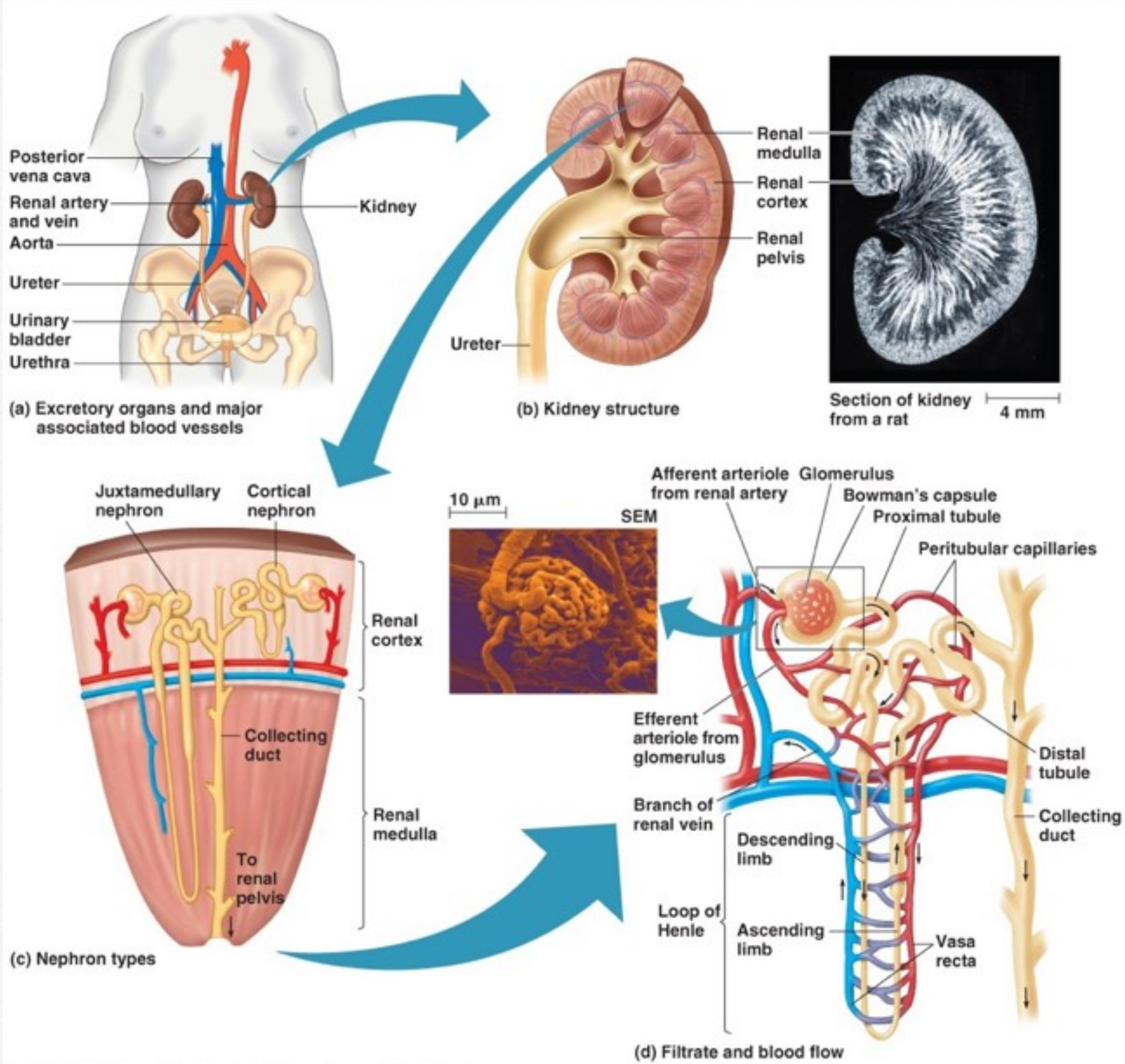
Text

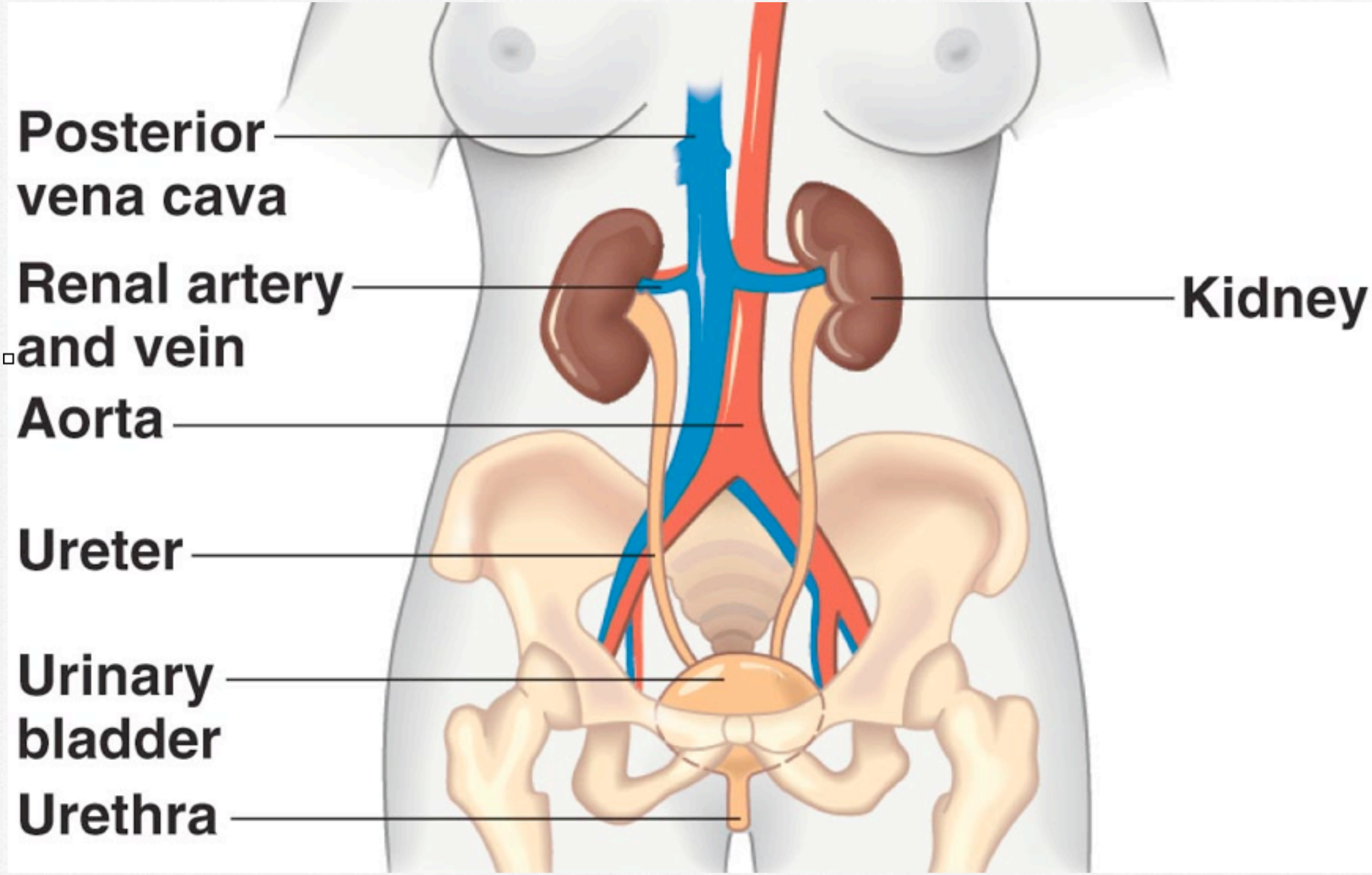
Good Solutes
and Water

body fluid that bathes
cells, sorta like blood and
extracellular fluid combo

Mammalian Excretory System

- **Serve to regulate water and eliminate waste!**
- Nitrogenous waste is soluble and leaves in the urine
- Mammalian kidneys have the ability to produce dilute or concentrated urine depending the environmental circumstances


Posterior vena cava
Renal artery and vein
Aorta
Ureter
Urinary bladder
Urethra
Kidney
(a) Excretory organs and major associated blood vessels
Renal medulla
Renal cortex
Renal pelvis
Ureter
(b) Kidney structure
Section of kidney from a rat
4 mm
Juxtamedullary nephron
Cortical nephron
Renal cortex
Collecting duct
Renal medulla
To renal pelvis
(c) Nephron types
10 µm
SEM
Afferent arteriole from renal artery
Glomerulus
Bowman's capsule
Proximal tubule
Peritubular capillaries
Efferent arteriole from glomerulus
Branch of renal vein
Distal tubule
Collecting duct
Descending limb
Loop of Henle
Ascending limb
Vasa recta
(d) Filtrate and blood flow


Posterior
vena cava
Renal artery
and vein
Aorta
Ureter
Urinary
bladder
Urethra
Kidney

Mammalian kidneys filter blood

↓

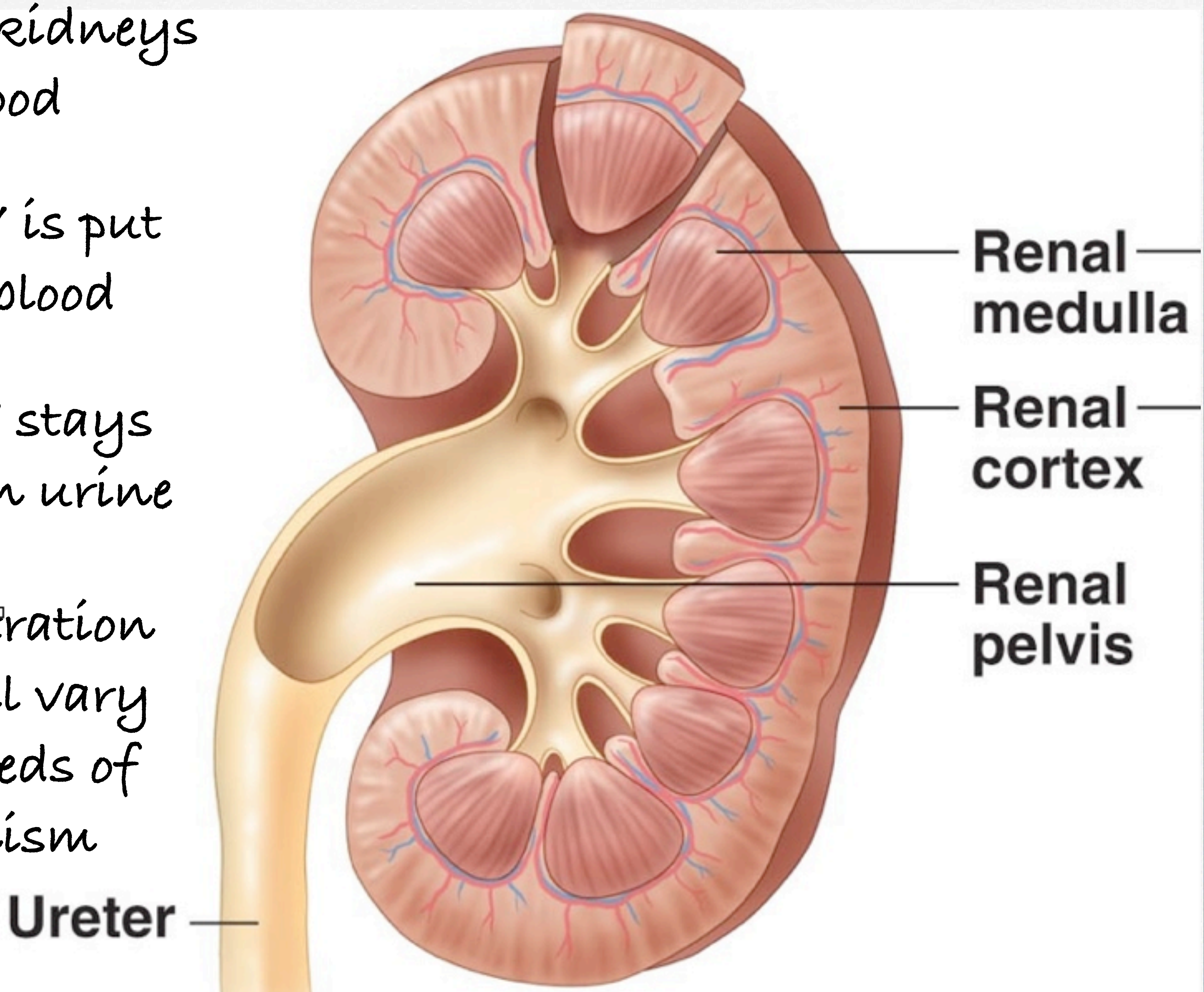
"Good stuff" is put back into blood

↓

"Bad stuff" stays and leaves in urine

↓

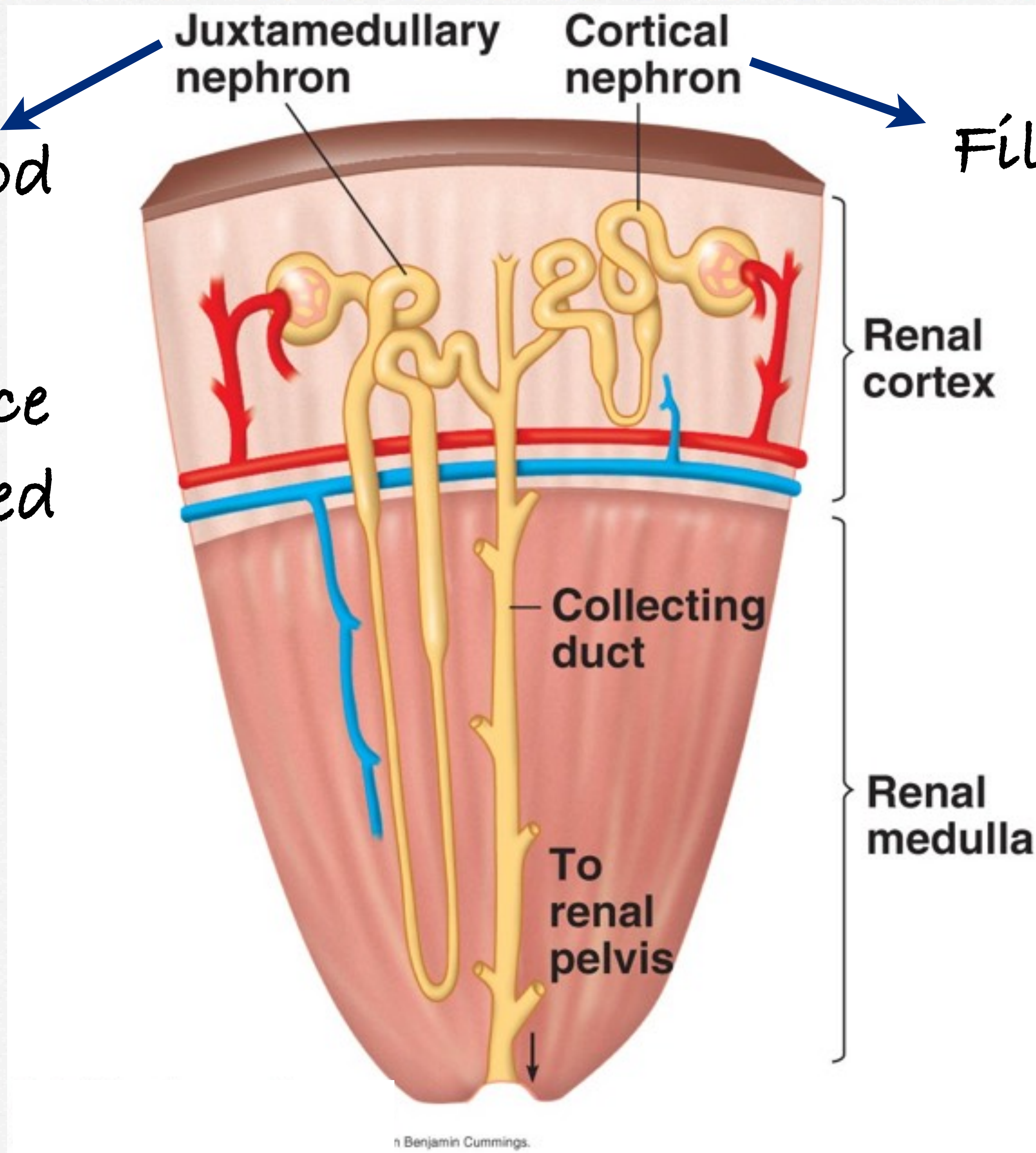
The concentration of urine will vary with the needs of the organism



Filters Blood

and

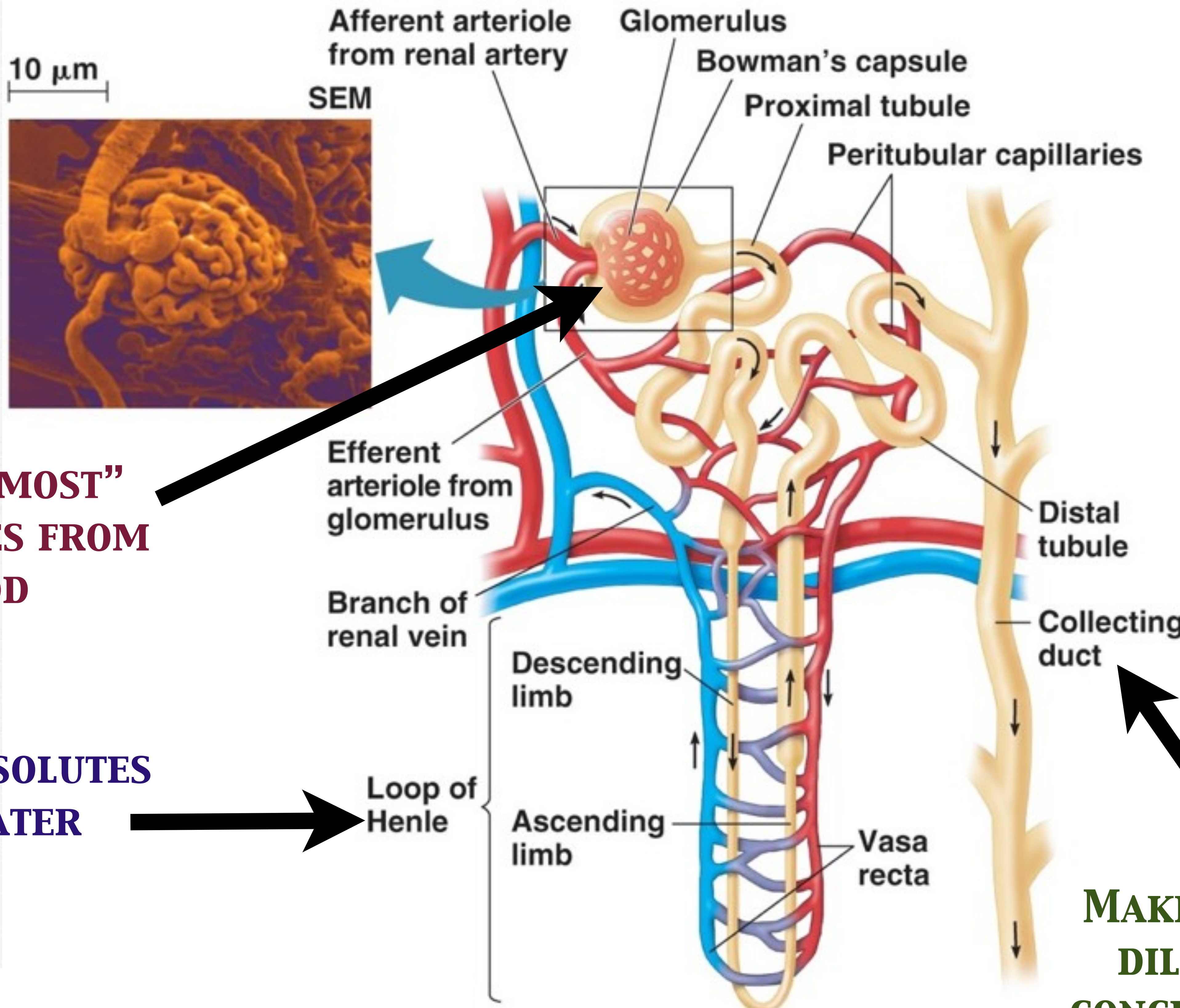
Can produce concentrated urine



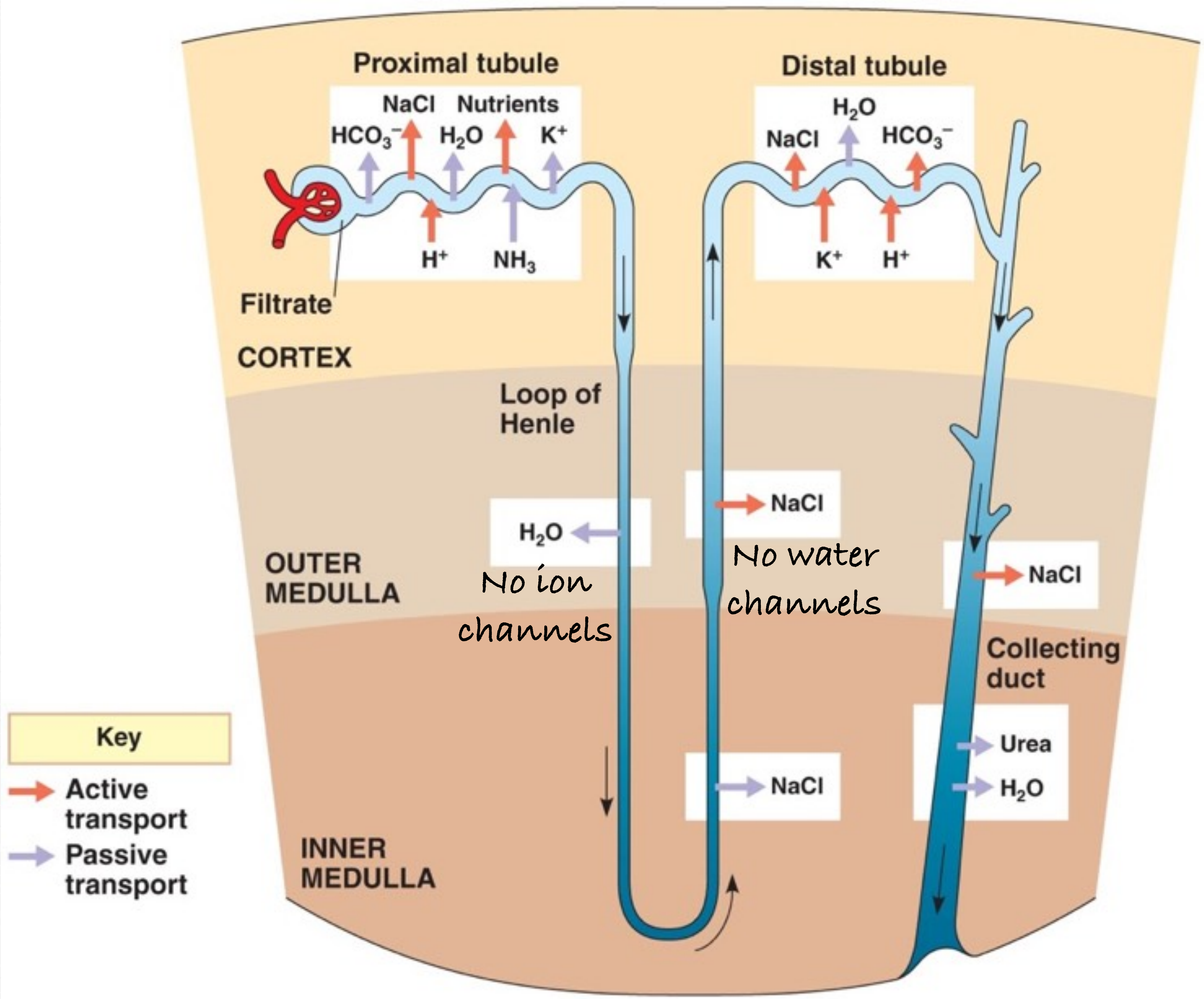
Filters Blood

Filters "most" substances from blood

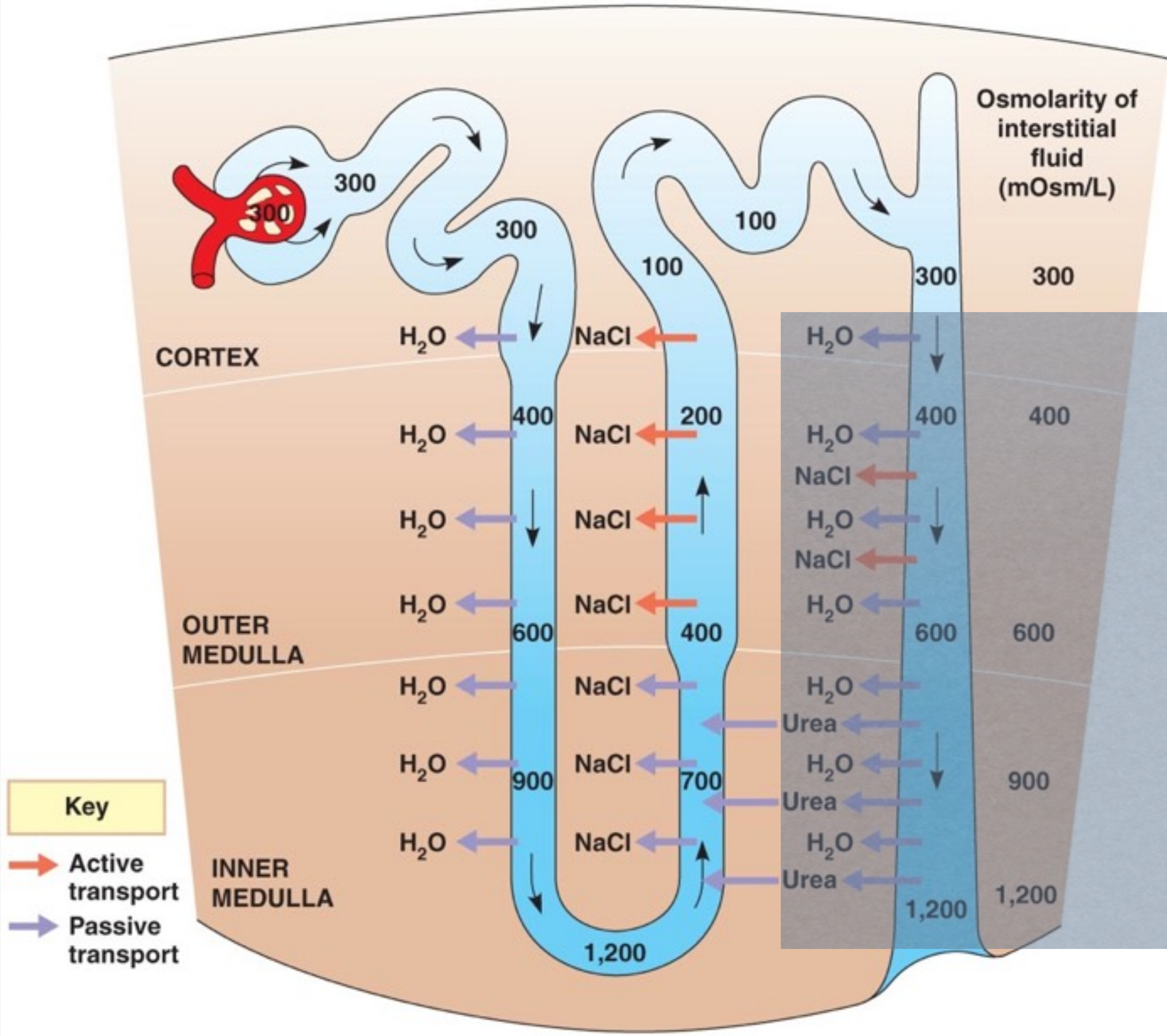
Reclaims solutes and water



Makes urine dilute or concentrated



Proximal tubule
NaCl
Nutrients
HCO_3^-
H_2O
K^+
H^+
NH_3
Filtrate
CORTEX
Distal tubule
H_2O
NaCl
HCO_3^-
K^+
H^+
Loop of Henle
H_2O
No ion channels
NaCl
No water channels
NaCl
OUTER MEDULLA
Collecting duct
Urea
H_2O
NaCl
INNER MEDULLA
Key
Active transport
Passive transport



THESE CHANNELS ARE UNDER HORMONAL CONTROL SO THAT THE BODY CAN REGULATE ITS WATER NEEDS

Adaptations of Kidneys

- Vertebrate animals occupy a wide range of habitats
  - Rain Forests to Deserts
  - Salty Lakes to Pure Mountain Streams
- Variation in kidney structure allows it to function according to the demands of the specific habitat

Mammals

- Long "loops of Henle" (juxtamedullary nephrons)allow terrestrial mammals to produce concentrated urine
- Hyperosmotic urine is key adaptation for land mammals, it conserves much water
- Aquatic mammals have much shorter nephrons, because the selective pressure for long nephrons was not as great

Birds & Reptiles

- These organisms live in very dehydrating environments
- They do not have long nephrons like mammals
- Instead they excrete their nitrogenous waste as uric acid which requires little to no water

Freshwater Fish & Amphibians

- These organisms live in a hypoosmotic environment
- They have many nephrons to produce large volumes of dilute urine
- They have to conserve salts!...by reabsorbing them in the distal tubules and leave water behind

Marine Bony Fish

- These organisms live in a hyperosmotic environment
- They gain salts and lose water to their surroundings
- They produce little urine, as a result that have few nephrons that are generally smaller

Learning Objectives:

LO 2.25 The student can construct explanations based on scientific evidence that homeostatic mechanisms reflect continuity due to common ancestry and/or divergence due to adaptation in different environments. [See SP 6.2]

LO 2.26 The student is able to analyze data to identify phylogenetic patterns or relationships, showing that homeostatic mechanisms reflect both continuity due to common ancestry and change due to evolution in different environments. [See SP 5.1]

LO 2.27 The student is able to connect differences in the environment with the evolution of homeostatic mechanisms. [See SP 7.1]