Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.

Enduring understanding 4.A: Interactions within biological systems lead to complex properties.

Essential knowledge 4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts.

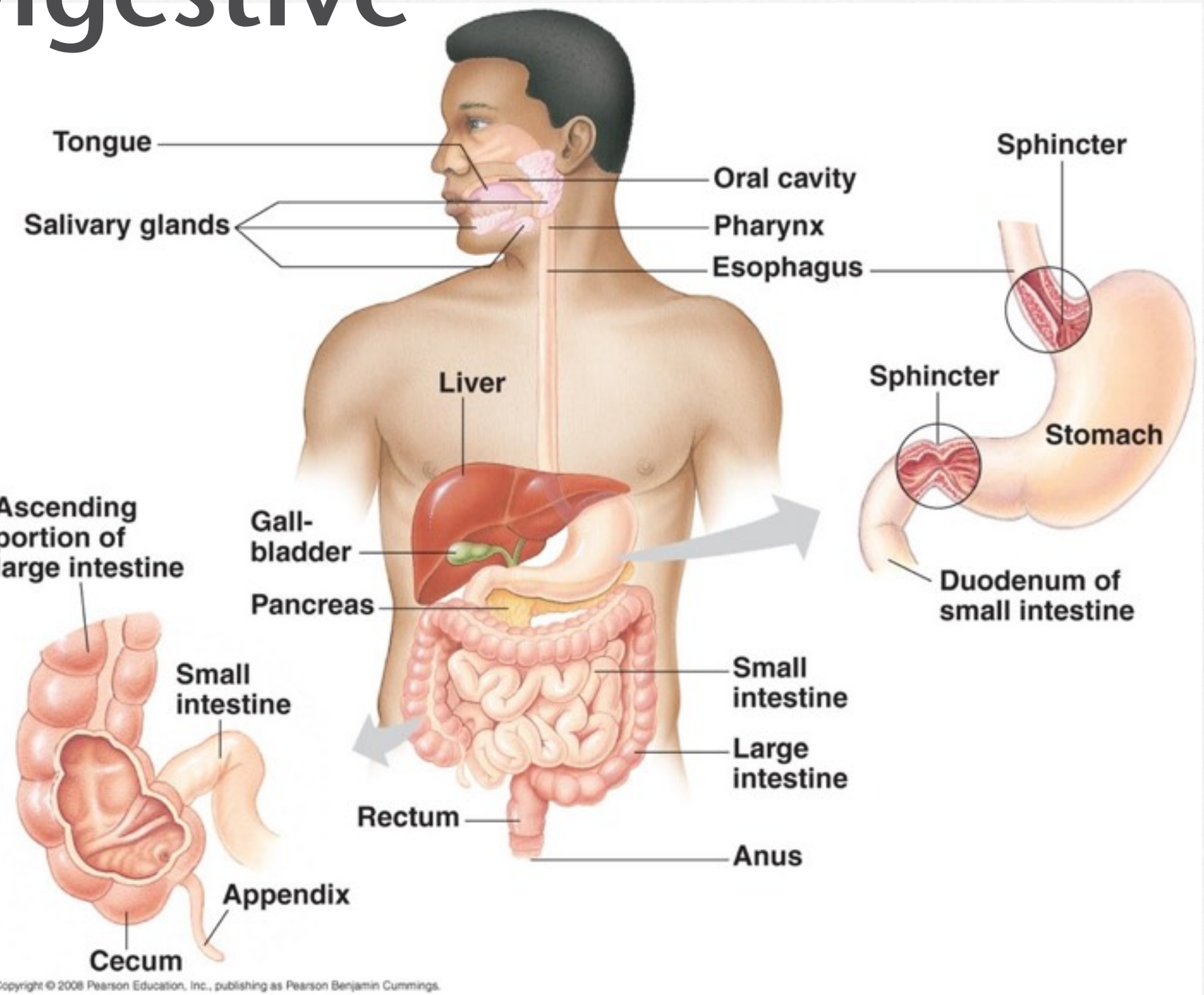
a. Interactions and coordination between organs provide essential biological activities.

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

-Stomach & Small Intestines
-Kidney & Bladder
-Root, Stem & Leaf

Stomach & Intestines

HumanDigestive System

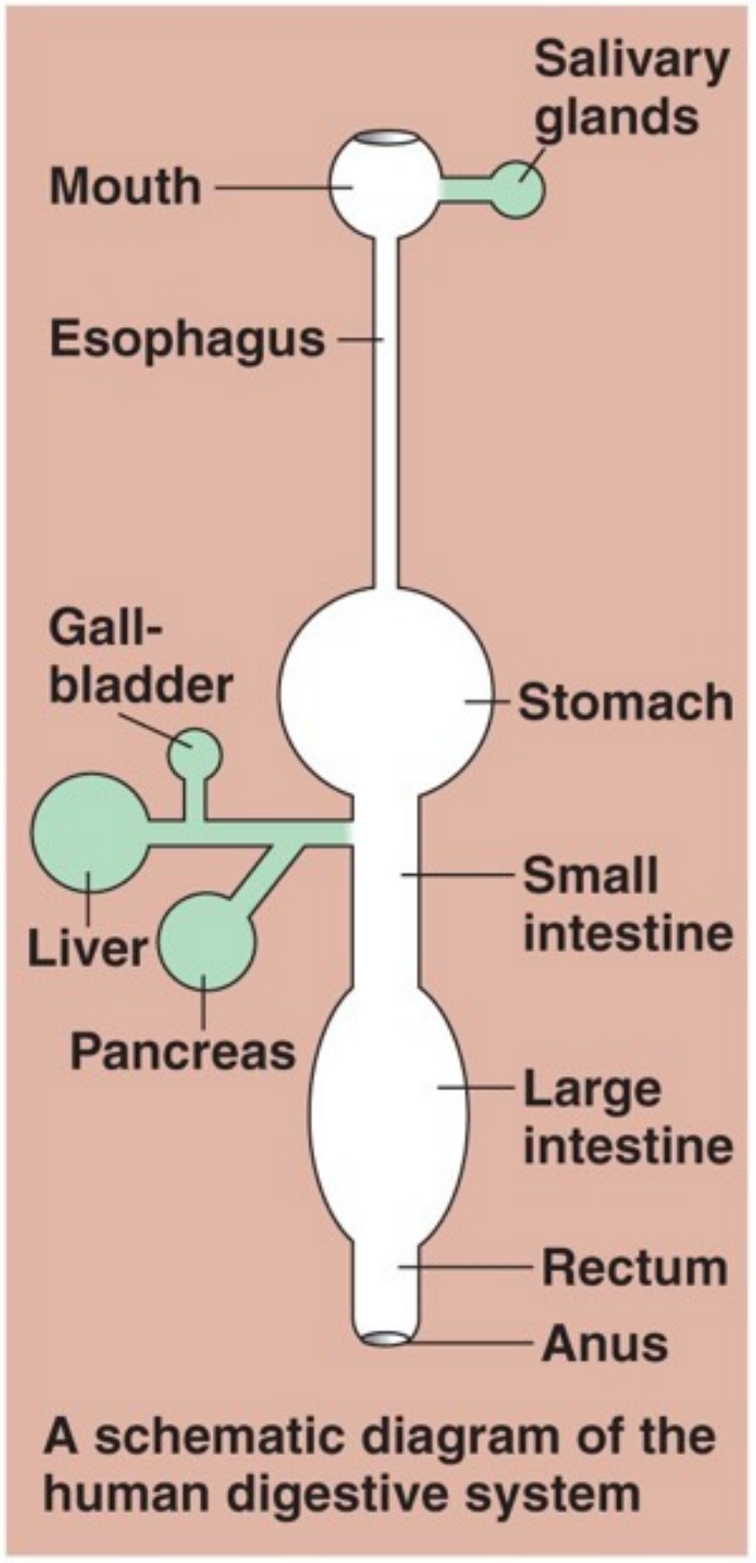


mechanical digestion

stores bile

makes bile
detoxifies

digestive enzymes



A schematic diagram of the human digestive system

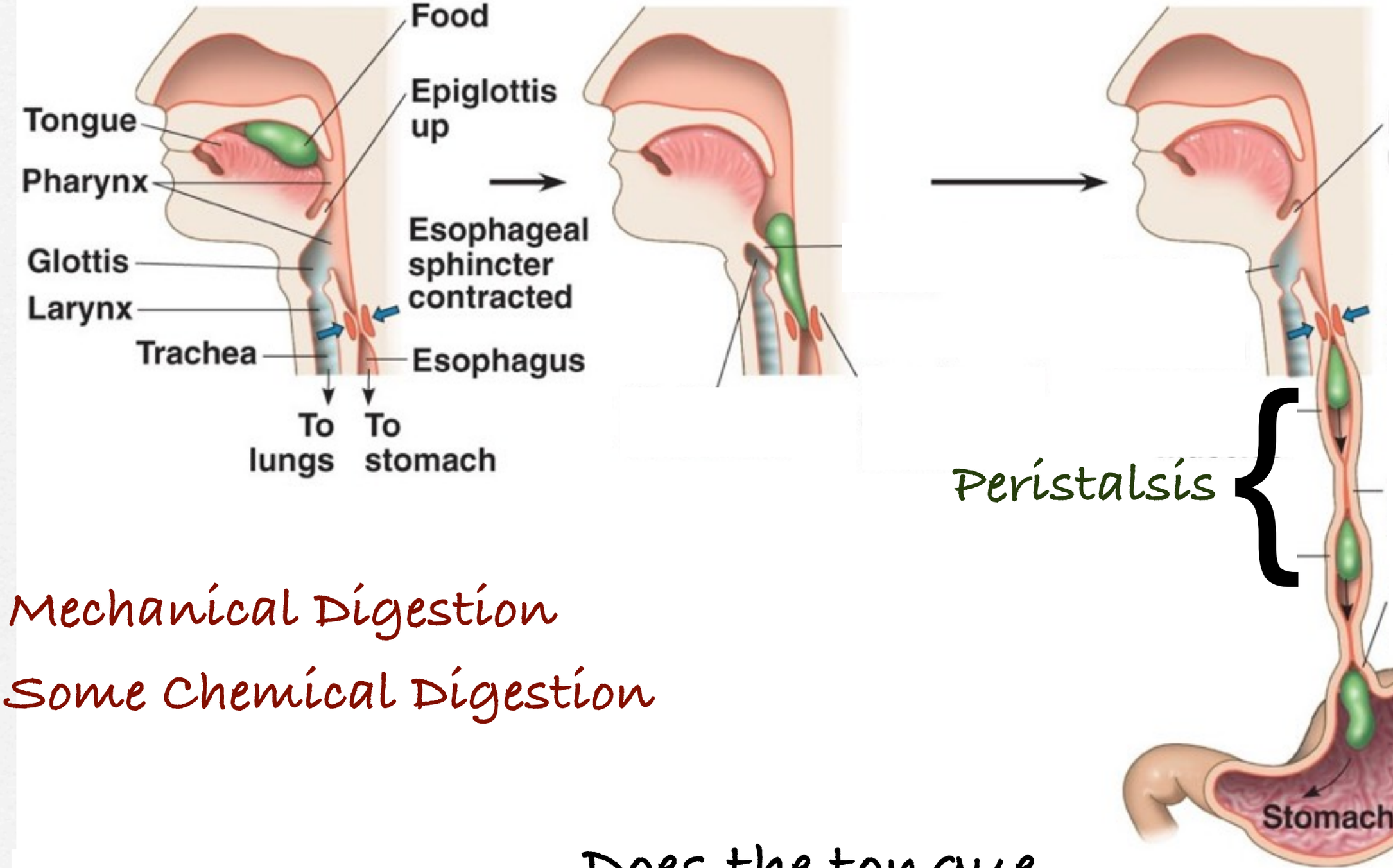
starts chemical digestion

food storage
mechanical digestion

chemical digestion
absorption

absorption

waste storage



Mechanical Digestion

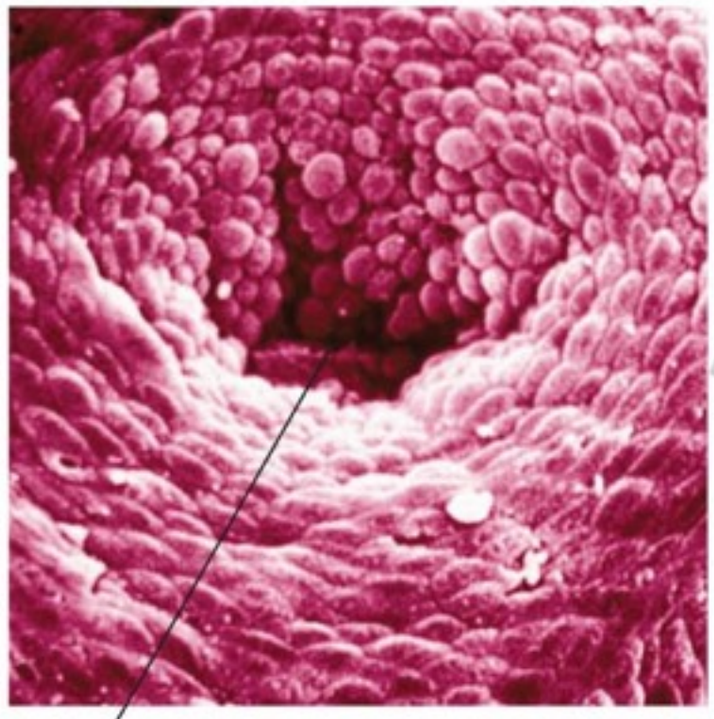
Some Chemical Digestion

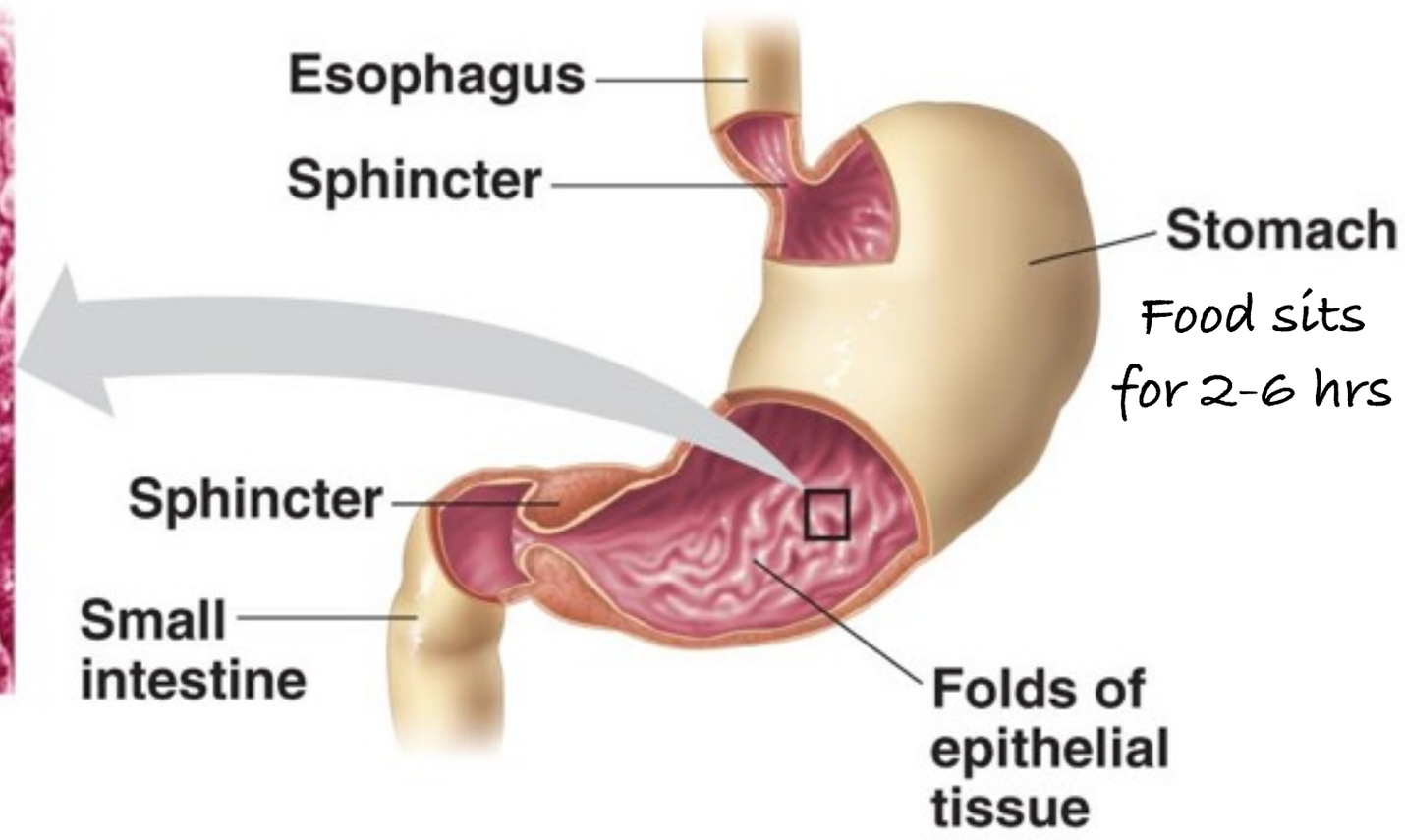
Does the tongue have any function?

Mainly Storage

Chemical Digestion

Some Mechanical Digestion

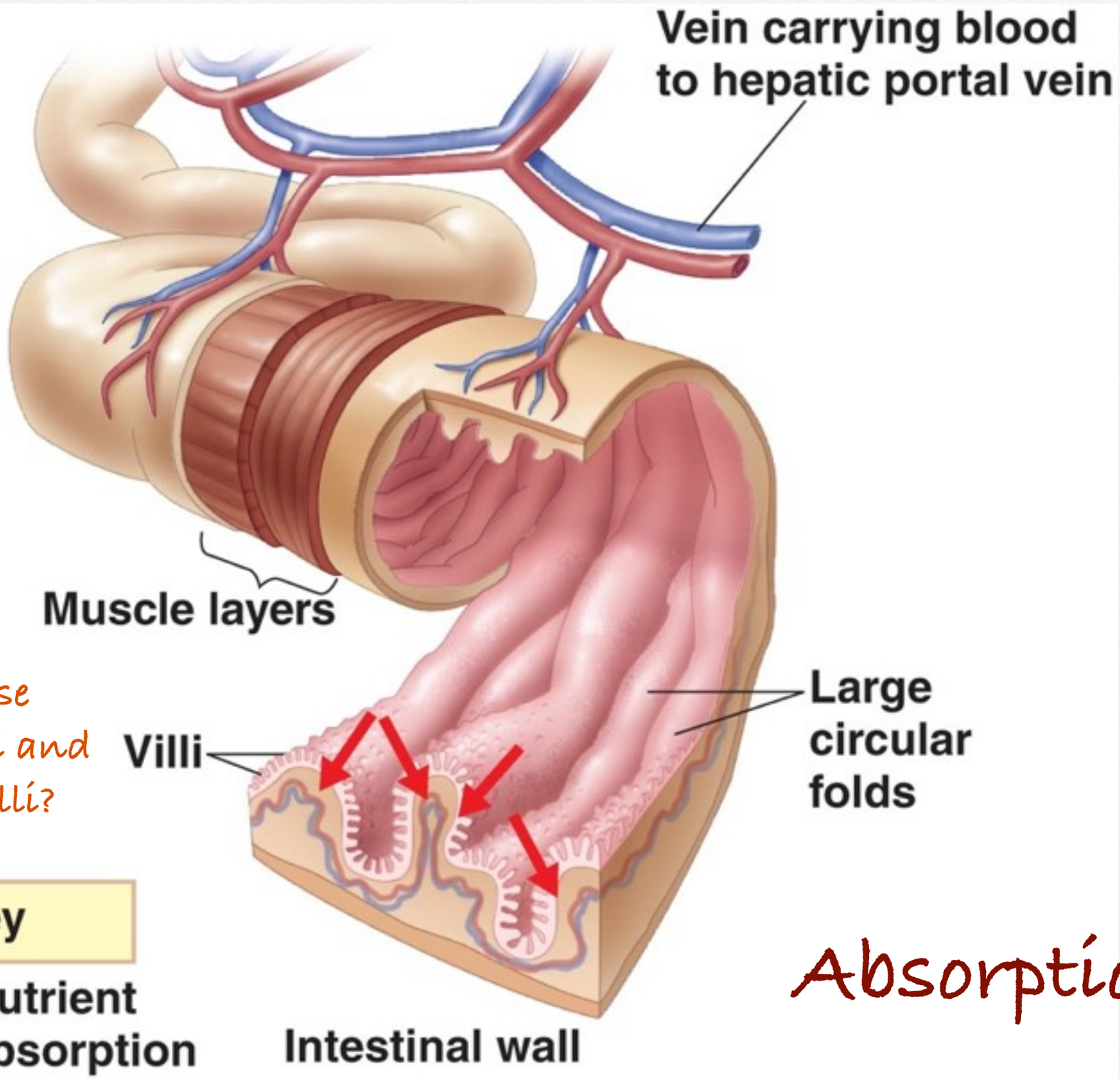




Very acidic...Why?

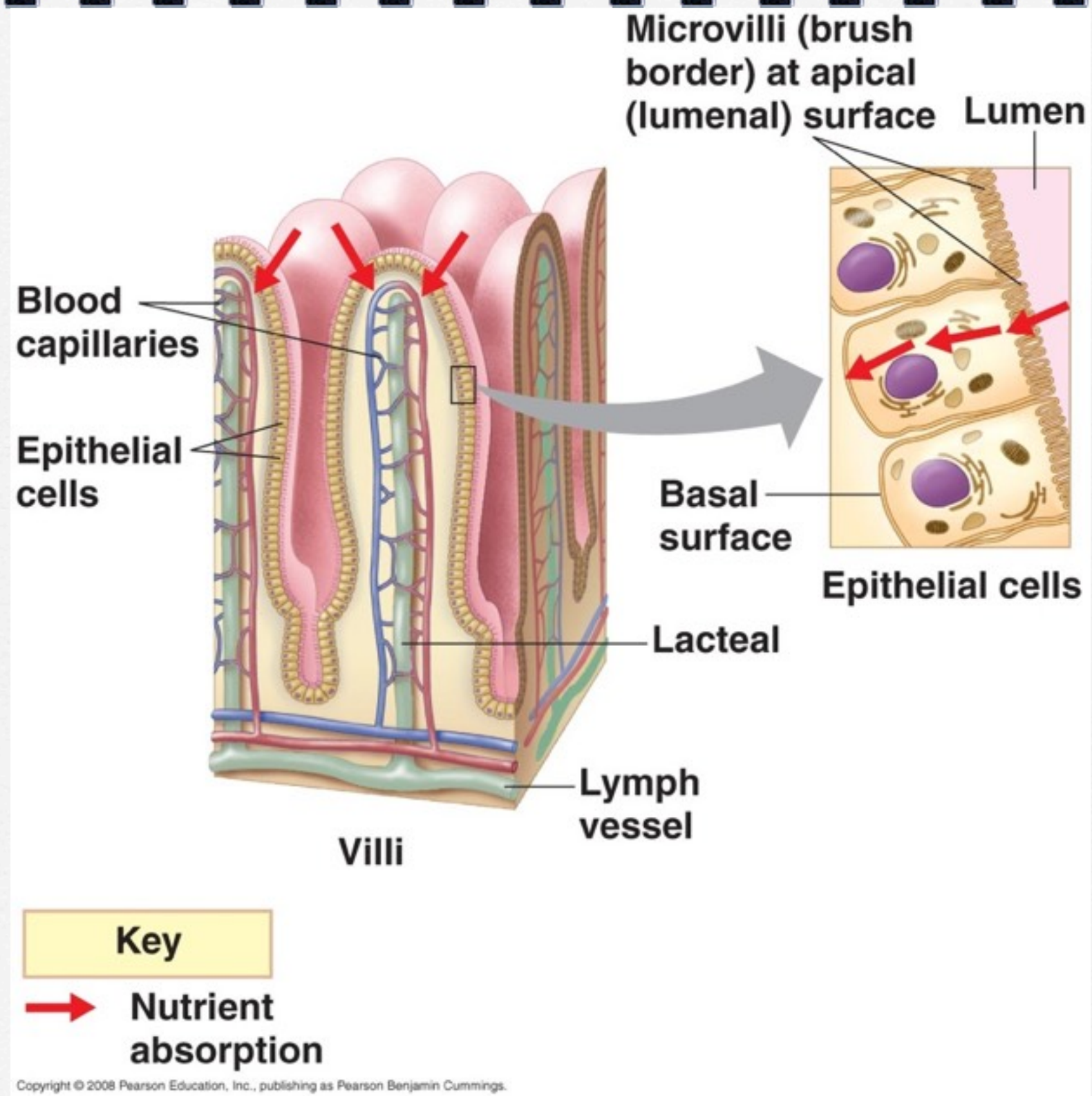
Chemical Digestion

over 20 feet long

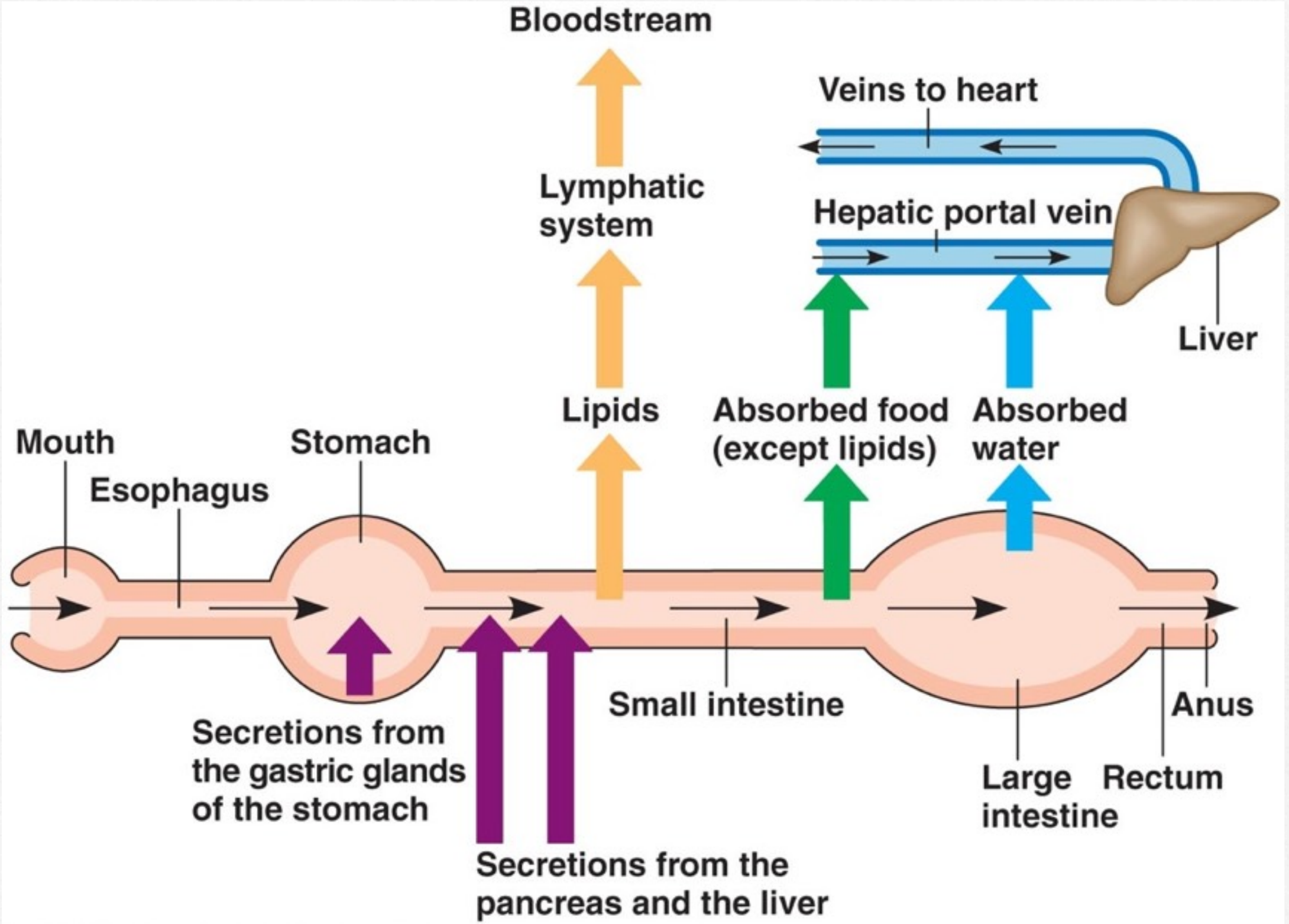


What is the purpose behind the folds, villi and the unseen microvilli?

Absorption



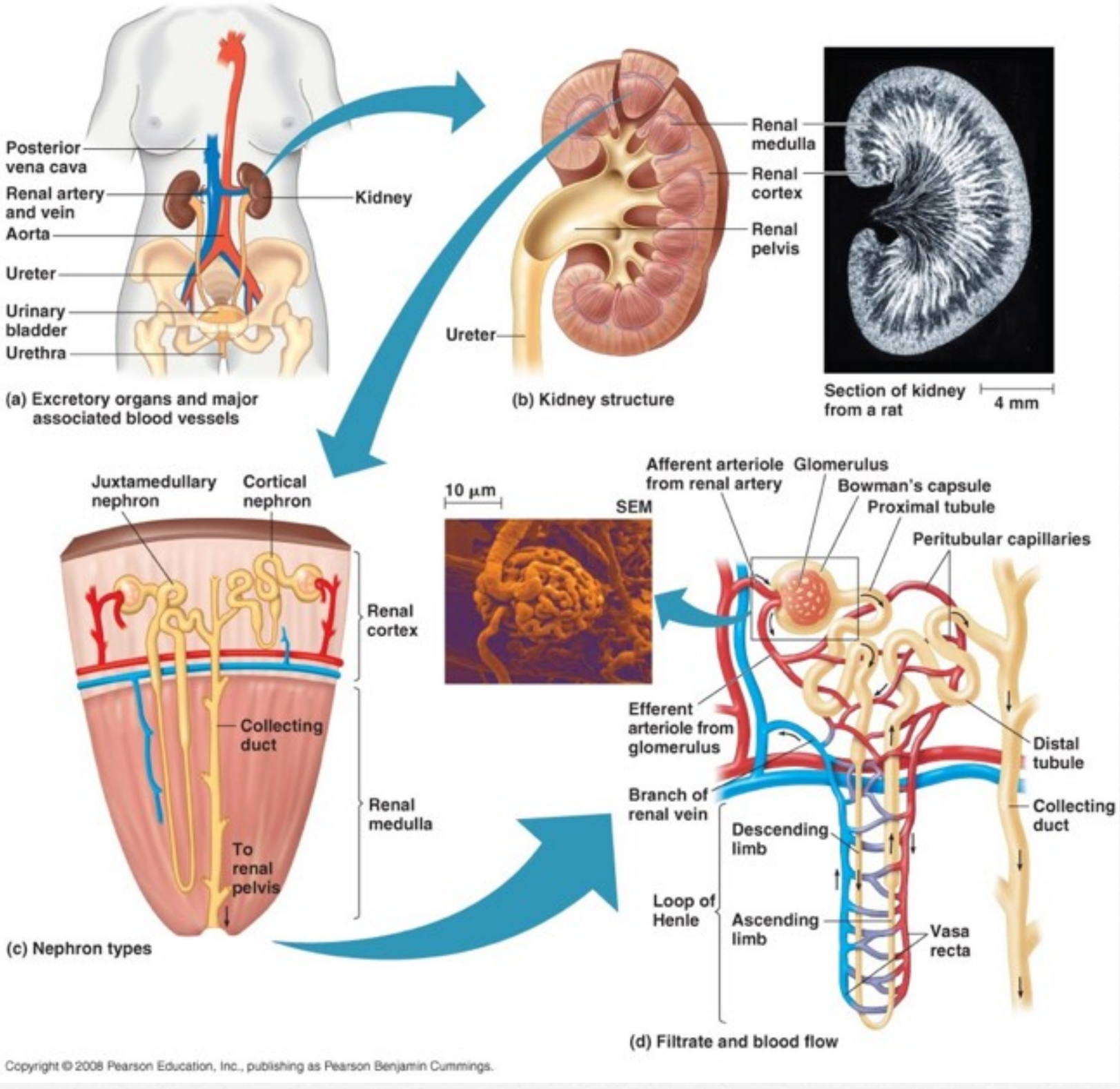
The absorption can be active or passive depending the nutrient

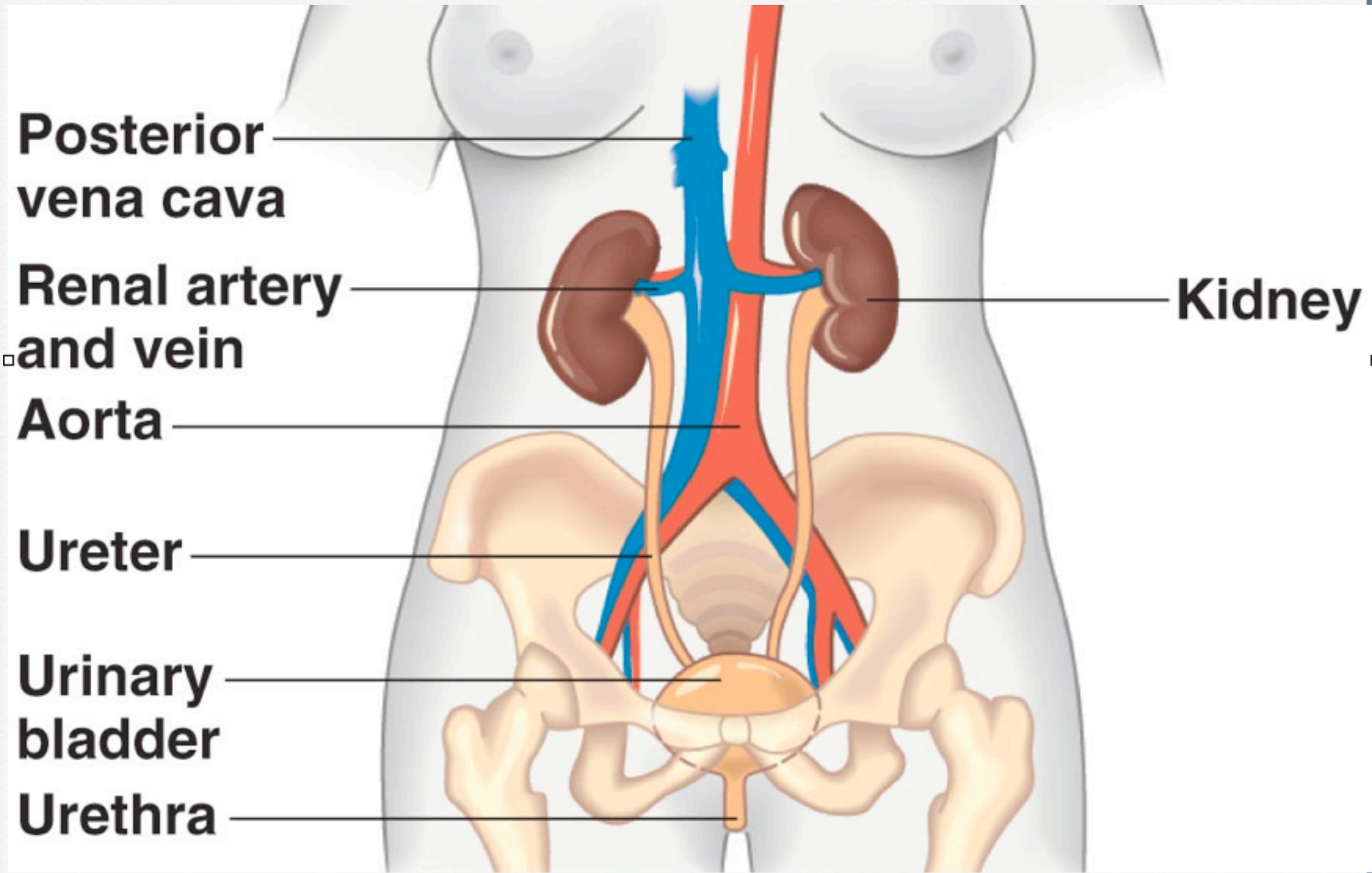


Kidney & Bladder

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

Mammalian kidneys filter blood

↓

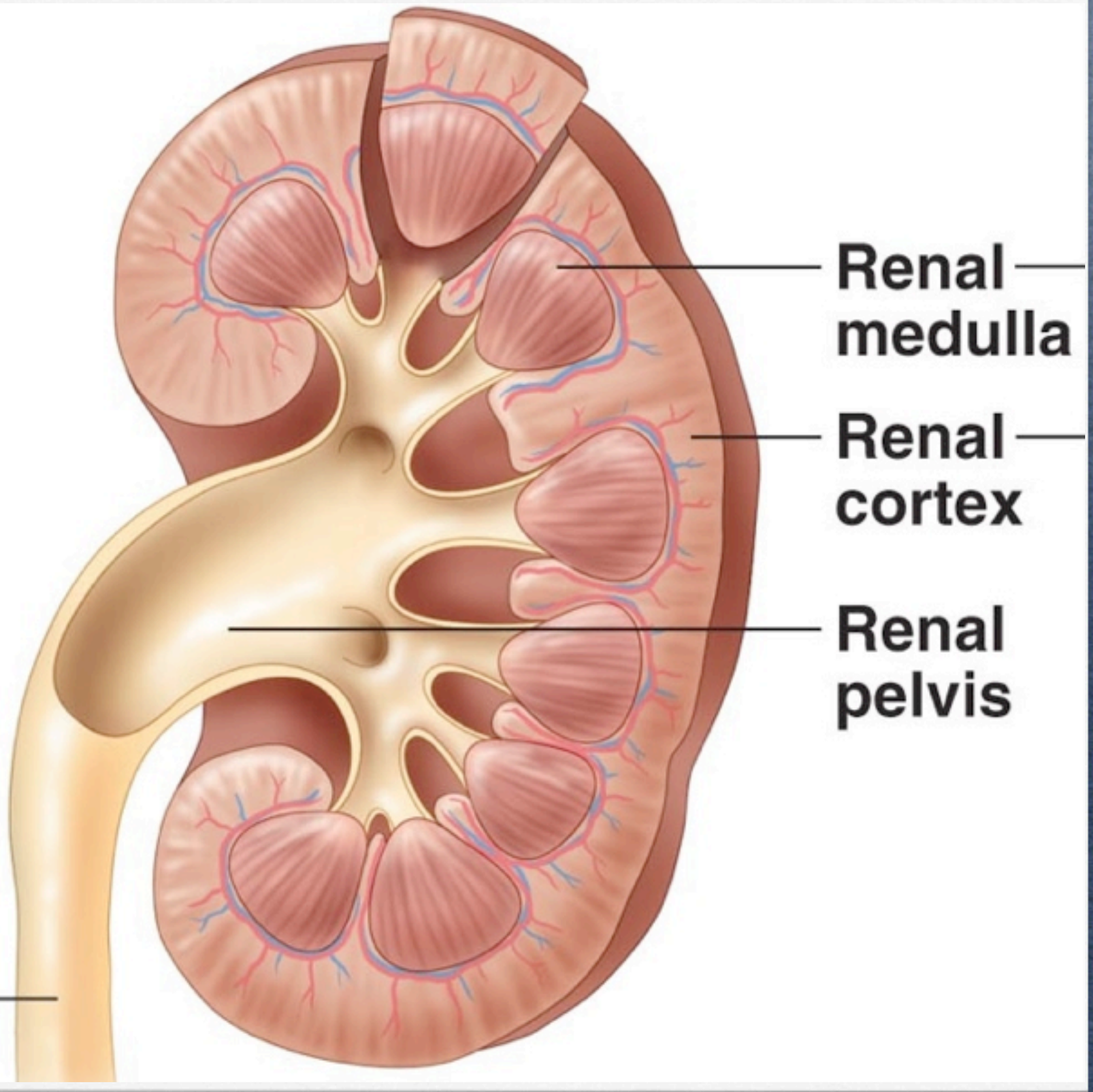
"Good stuff" is put back into blood

↓

"Bad stuff" stays and leaves in urine

↓

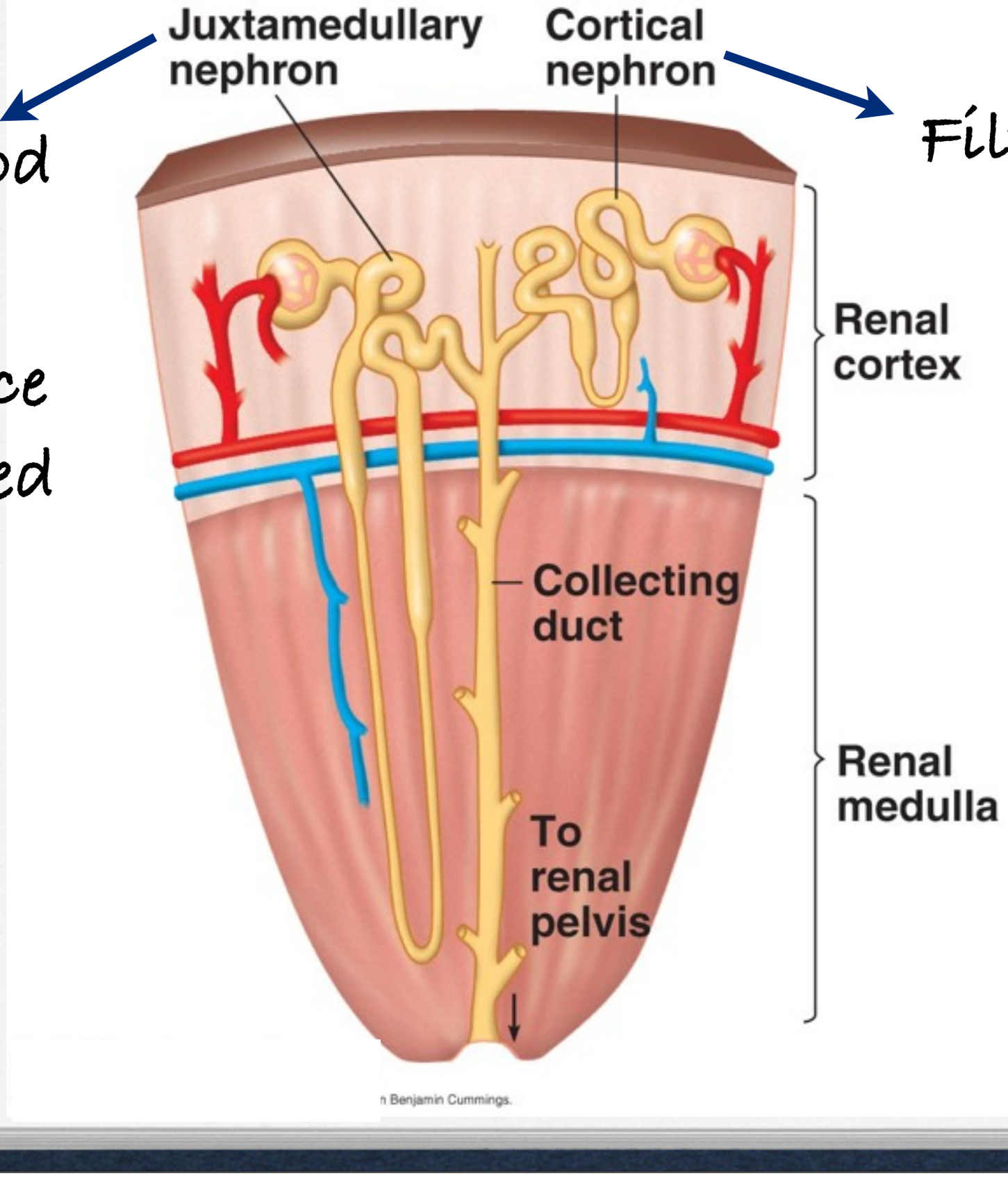
The concentration of urine will vary with the needs of the organism



Filters Blood

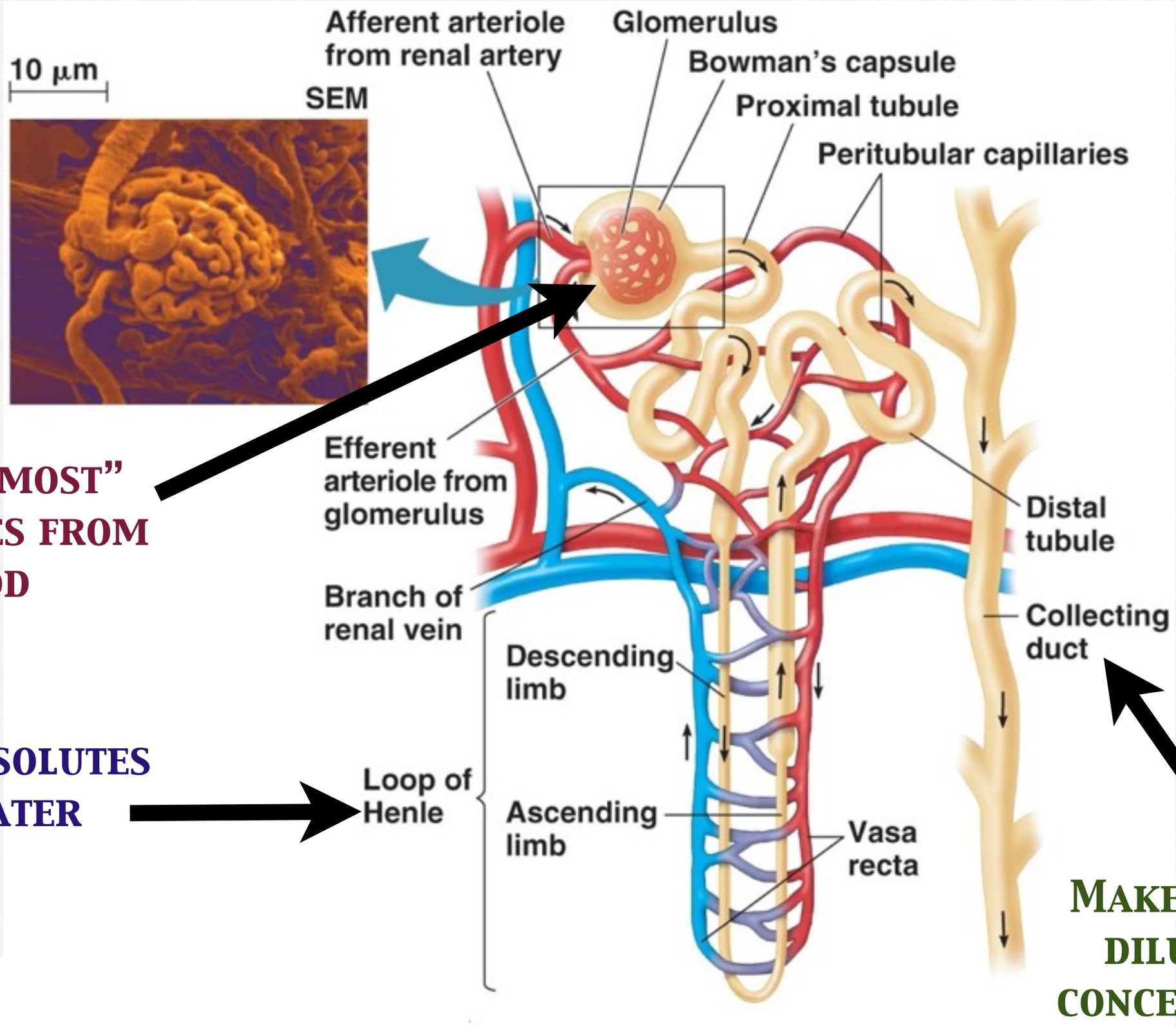
and

Can produce concentrated urine



Filters Blood

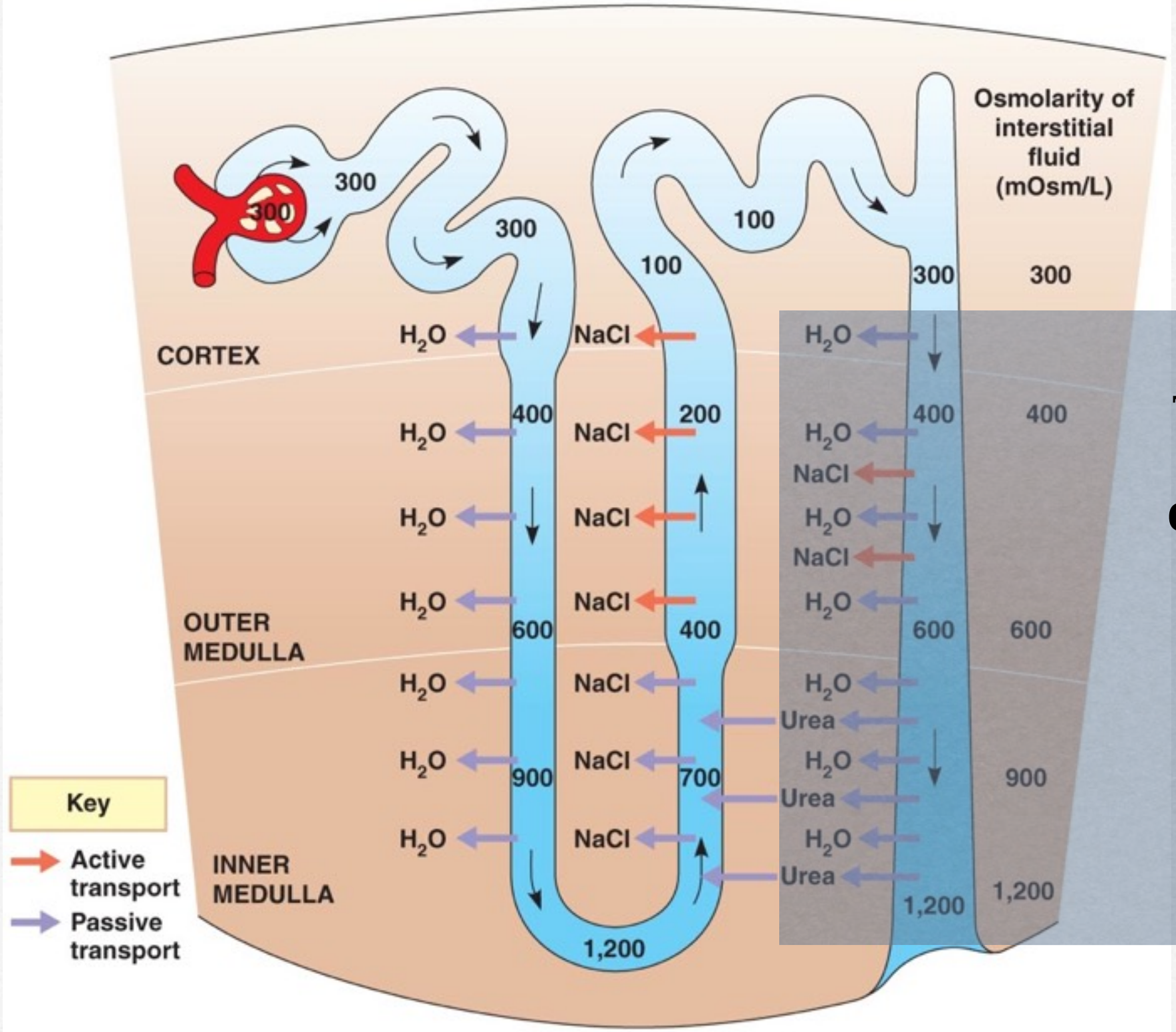
Friday, January 27, 17



FILTERS "MOST" SUBSTANCES FROM BLOOD

RECLAIMS SOLUTES AND WATER

MAKES URINE DILUTE OR CONCENTRATED



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

Roots, Stems & Leaves

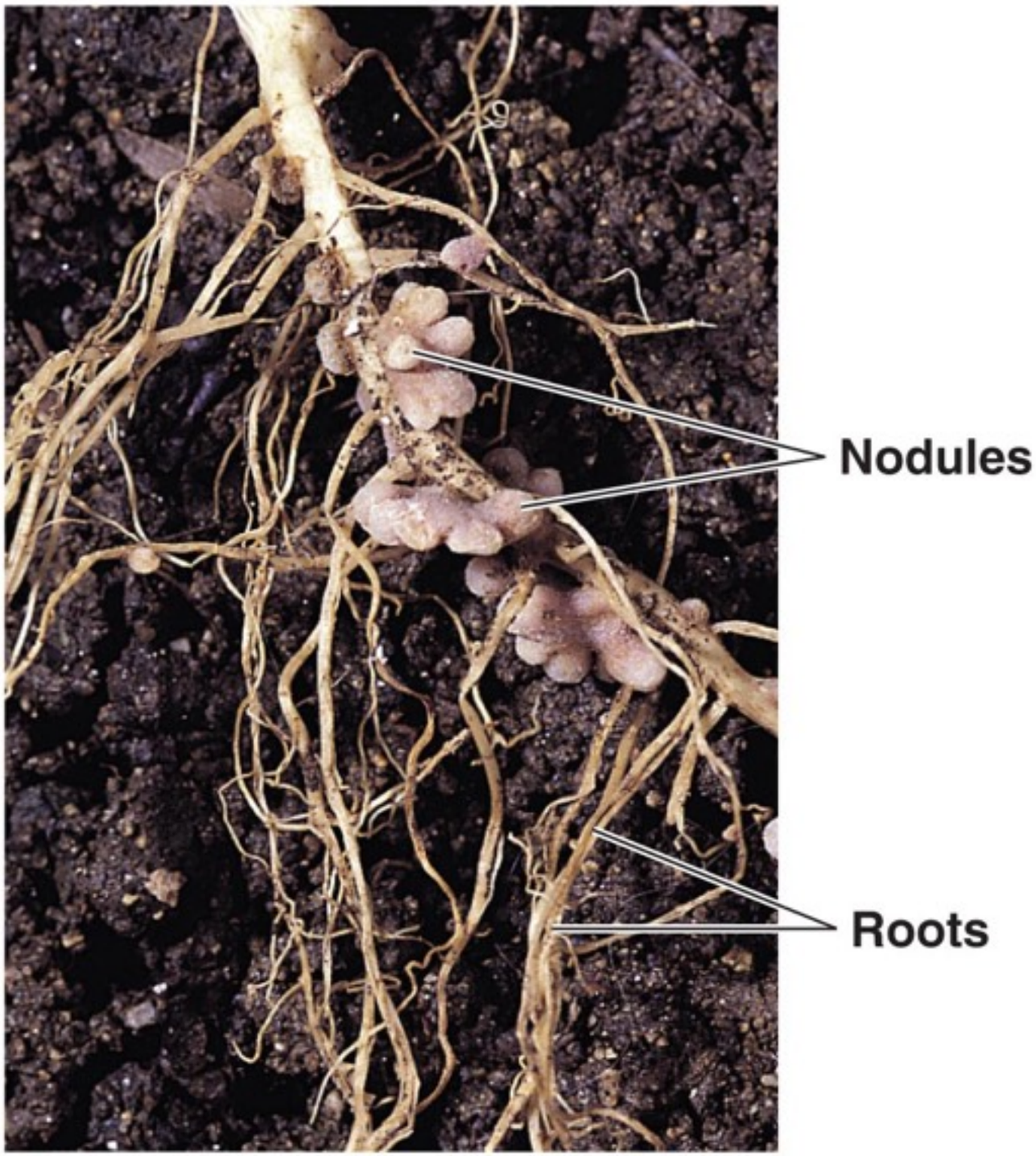
- **Emphasis on Nutrition**

Root Nodules

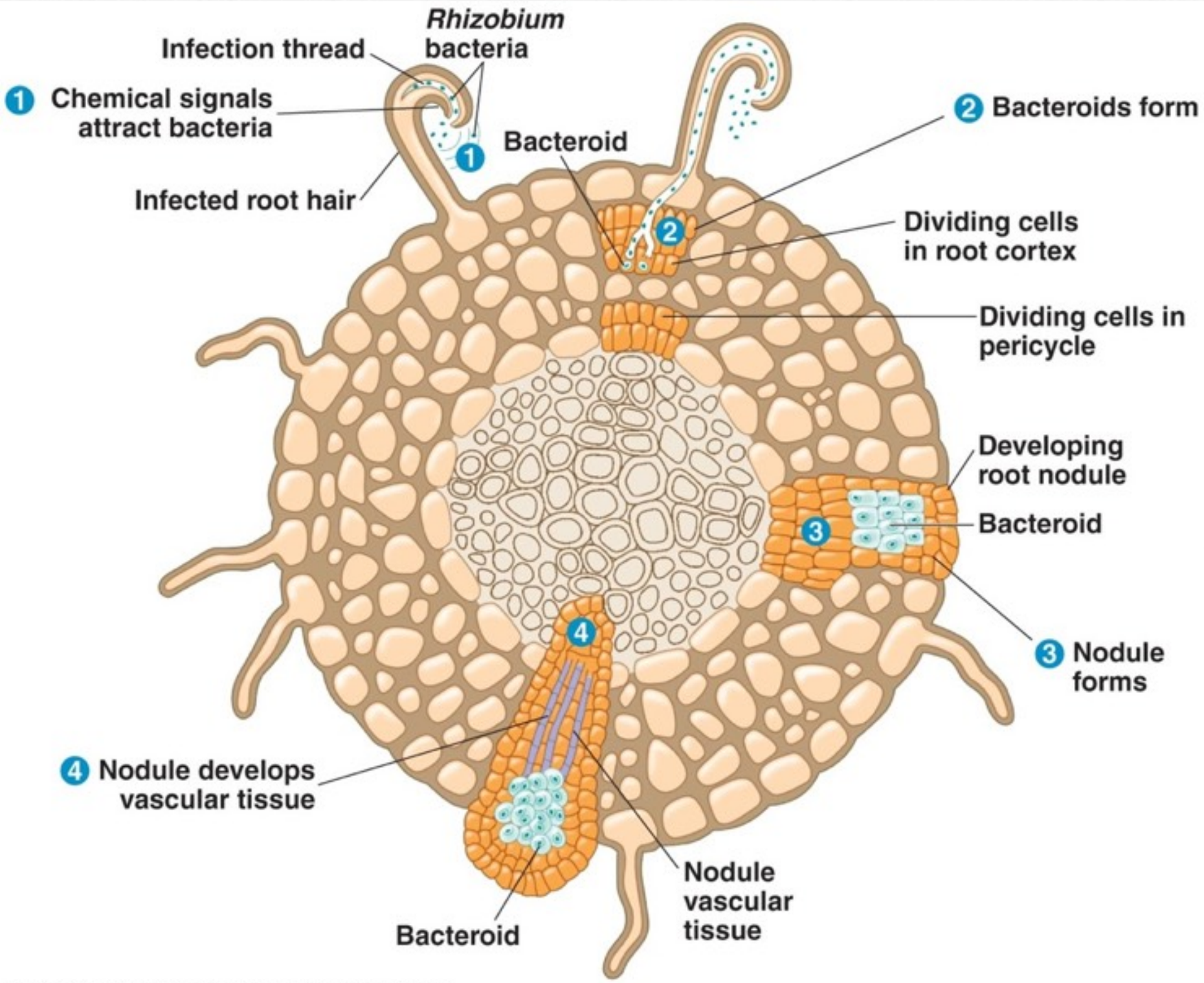
Plants

&

Prokaryotes



(a) Pea plant root



Plant provides sugar to the bacteria

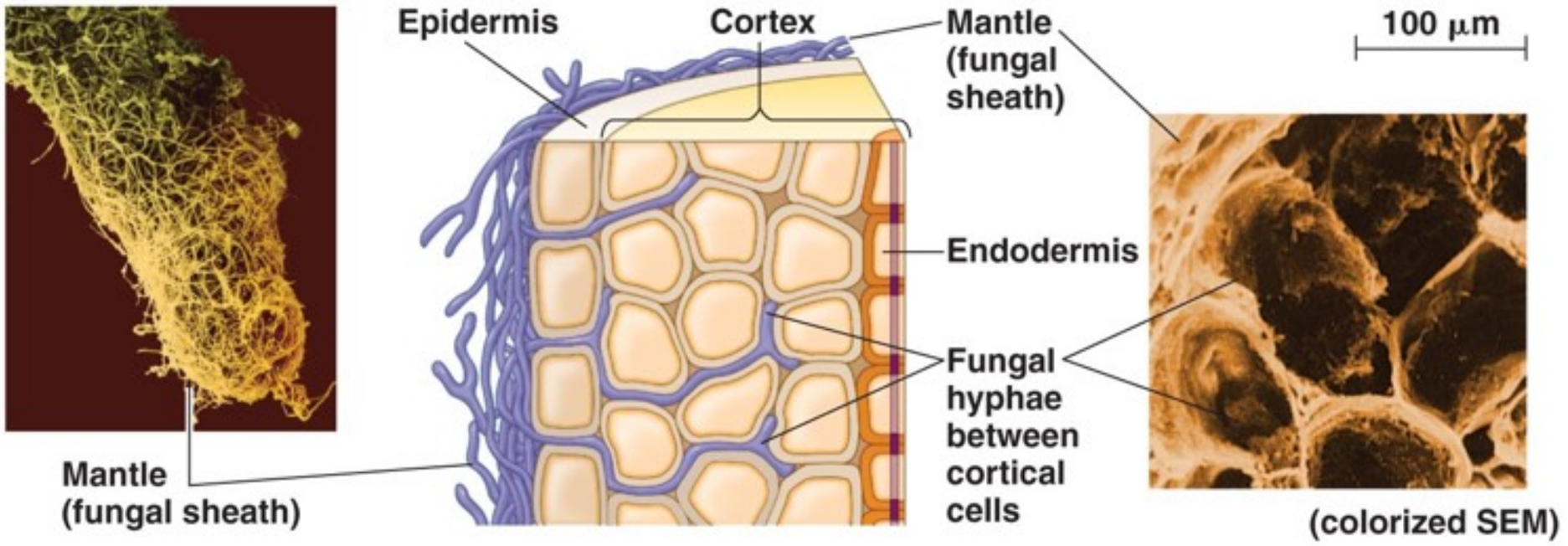
Bacteria provides nitrogen to the plant

Mycorrhizae

Plants

&

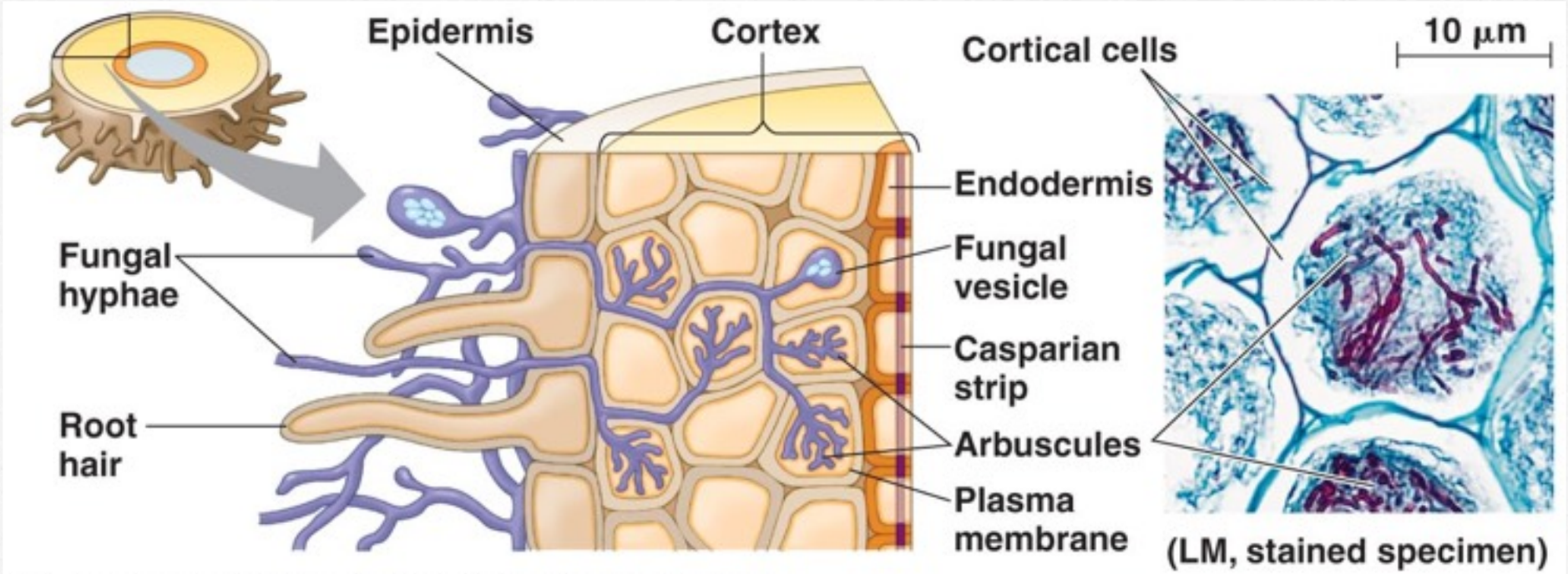
Fungi



(a) Ectomycorrhizae

Plant provides sugar to the fungi

Fungi provides water to the plant



(b) Arbuscular mycorrhizae (endomycorrhizae)

Roots, Stems & Leaves

- **Emphasis on Water**

Moving Water Through the Plant Body: Long Distance

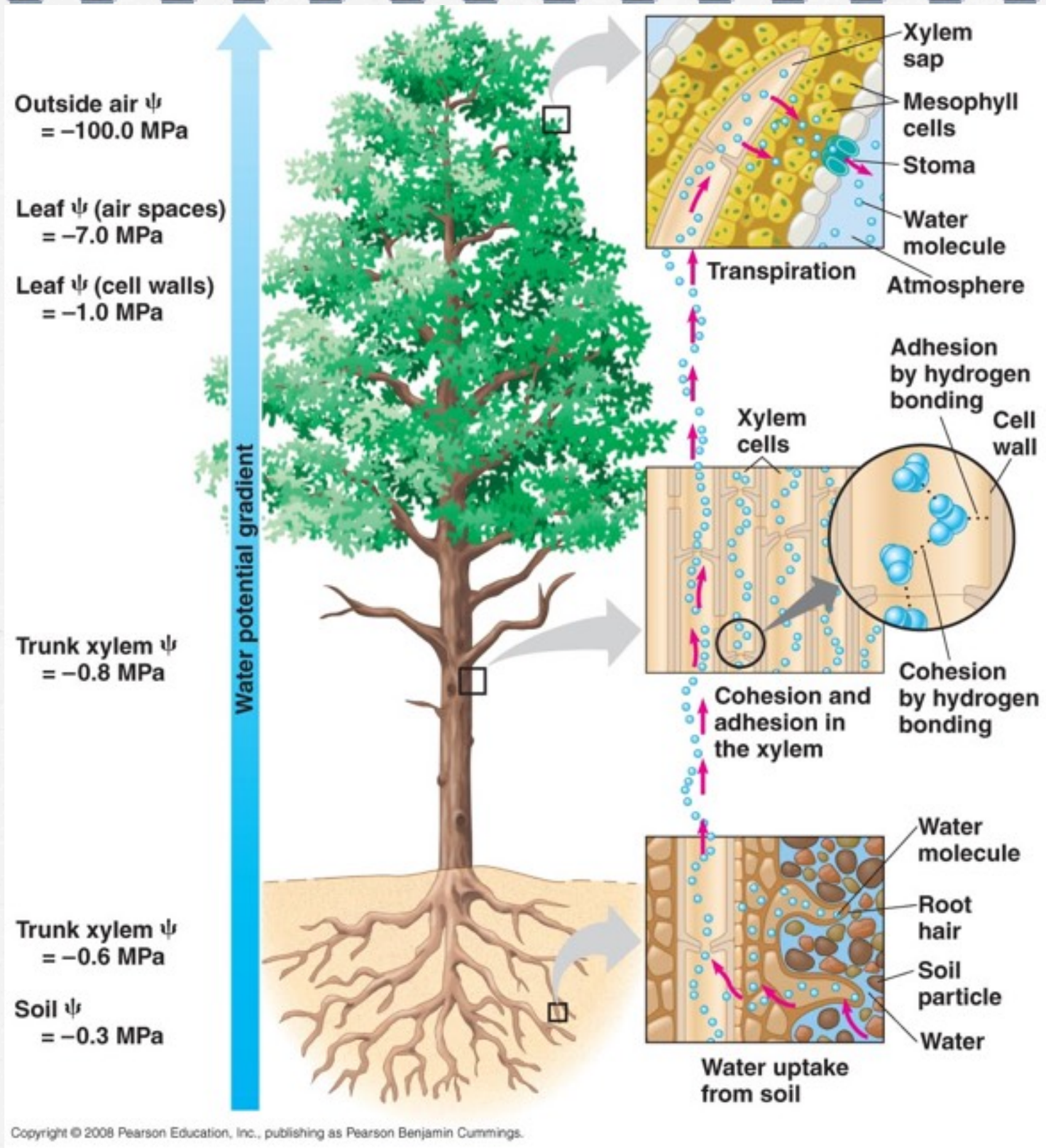
- Diffusion would be far too slow to move water long distances.
- BULK FLOW uses pressure gradients to move water over long distances
- using bulk flow, water moves from higher pressures to lower pressures
- Bulk flow is independent of solute concentration

Low pressure

TENSION

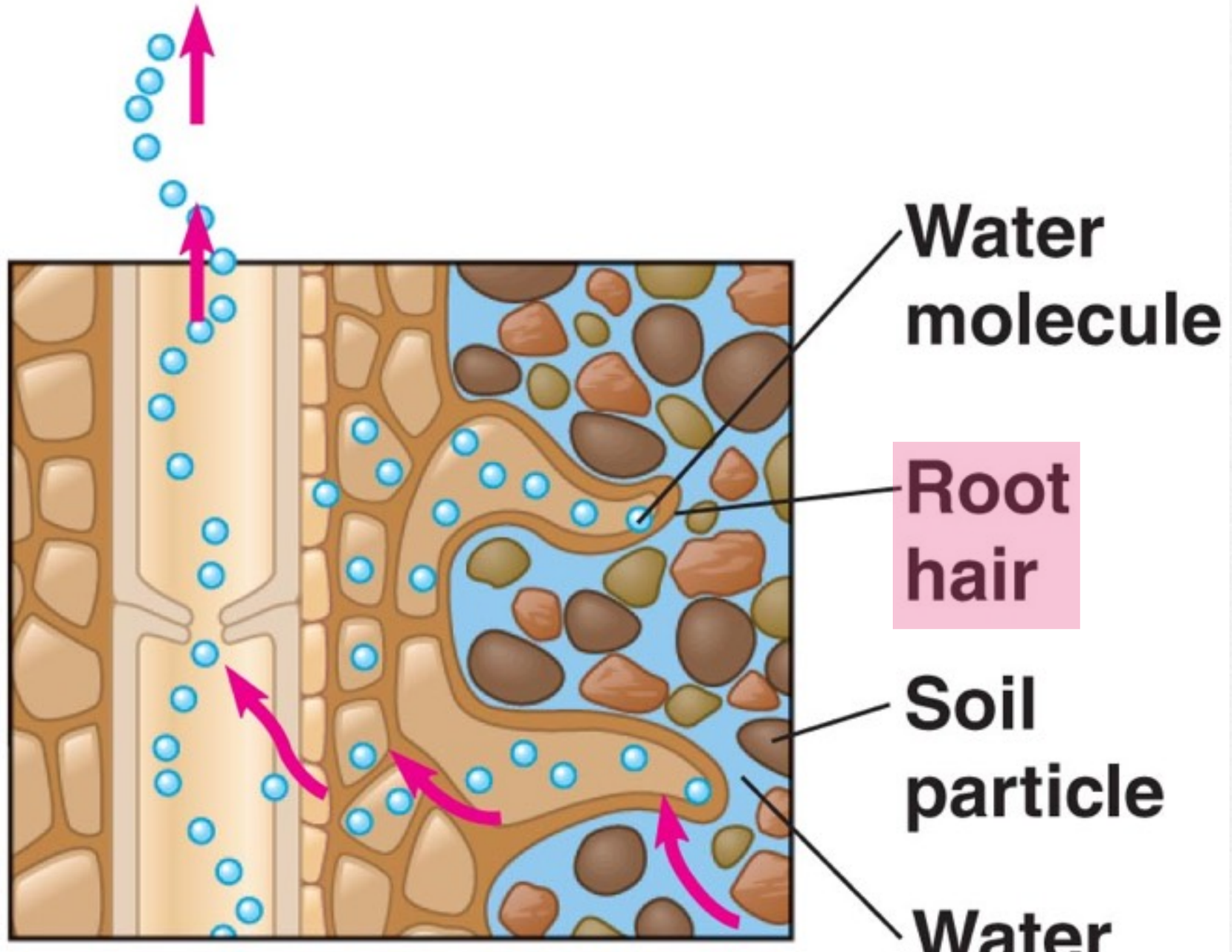
Water is pulled up

High pressure



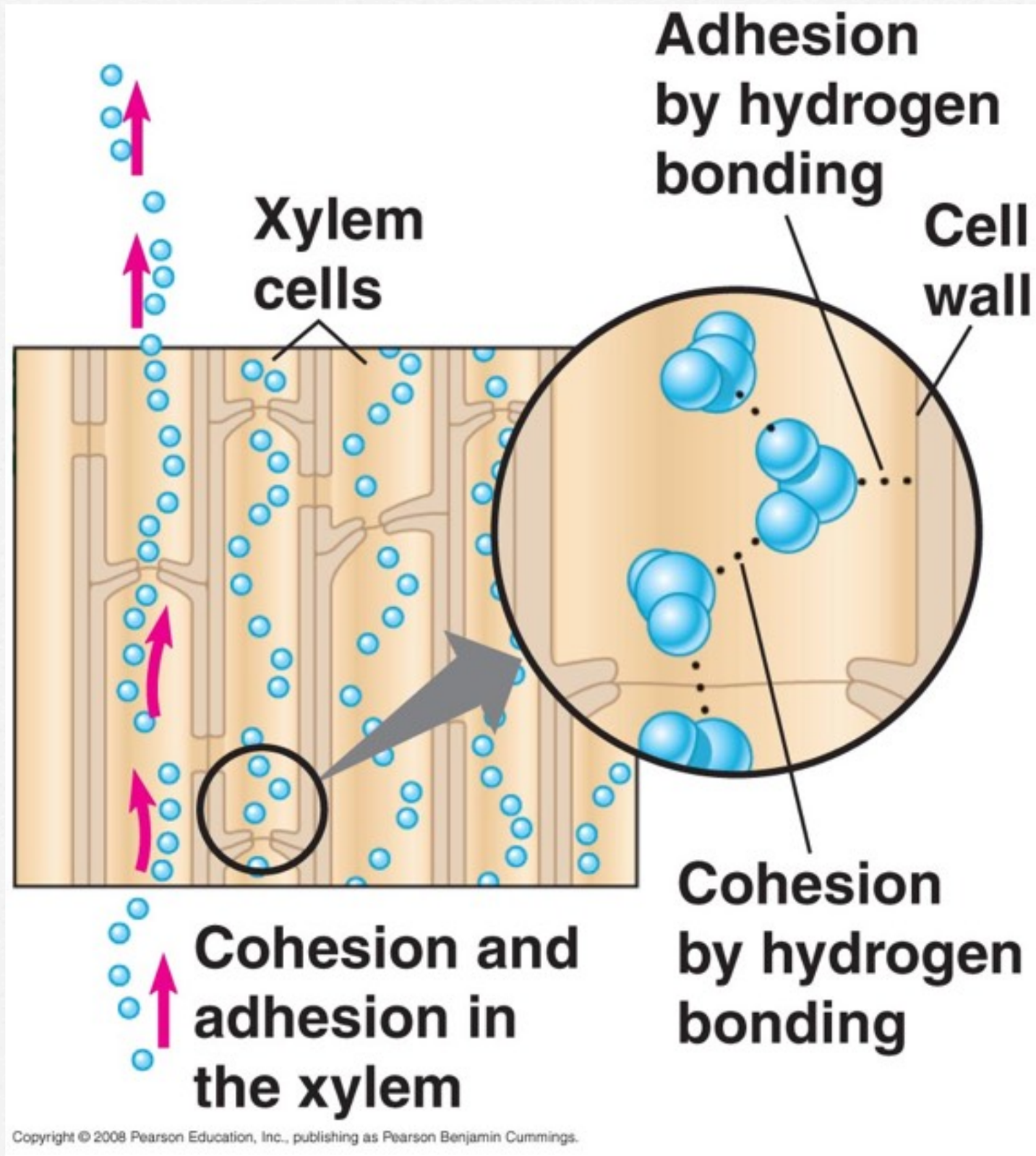
Absorption of water and minerals takes place at the tips of the roots, ROOT HAIRS (increase surface area)

Also aided by mycorrhizae



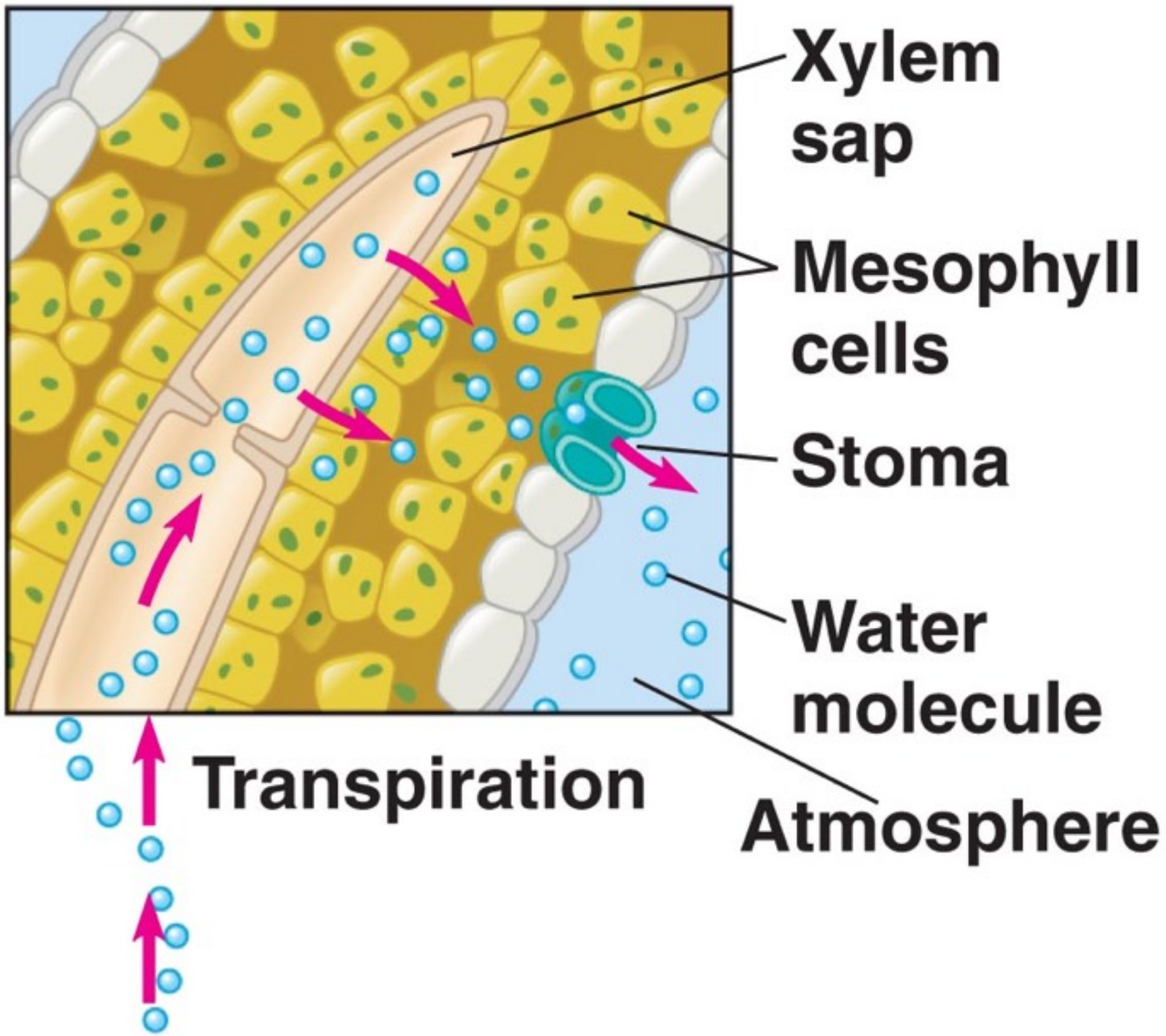
Water uptake from soil

Xylem cells are dead, hollow cells through which water (no sugars) is transported upward through the plant with no energy input

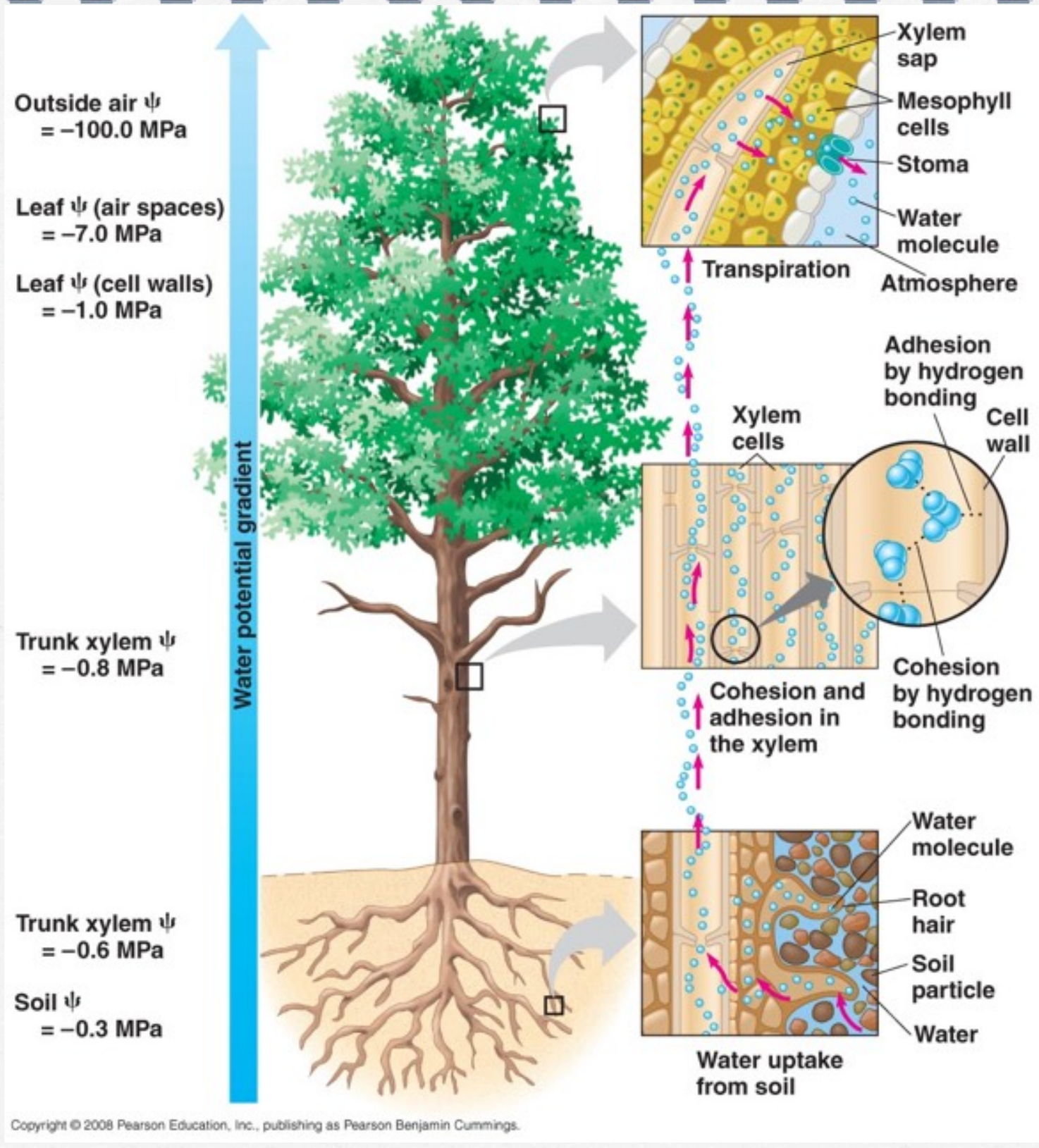


LEAF CROSS SECTION

Stoma are pores in the leaf that allow gas exchange, in this case water vapor



Transpiration will be greatest during bright, hot, dry and windy days. These conditions increase the rate of evaporation and subsequent transpiration. Assuming of course the soil has water.



Essential knowledge 4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts.

b. Interactions and coordination between systems provide essential biological activities.

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

-Respiratory & Circulatory
-Nervous & Muscular
-Plant vascular & Leaf

Respiratory & Circulatory

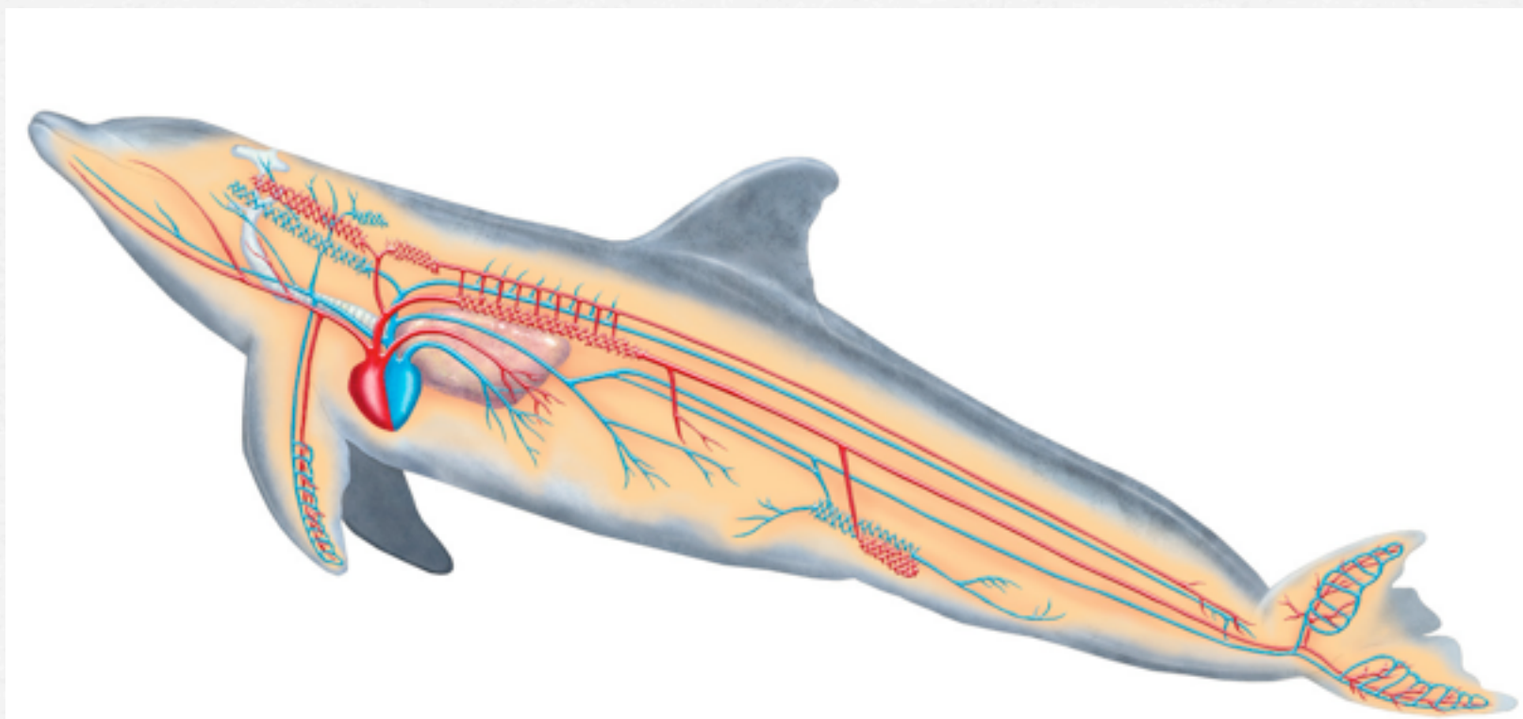
Circulatory Systems-
Link Exchange Surfaces

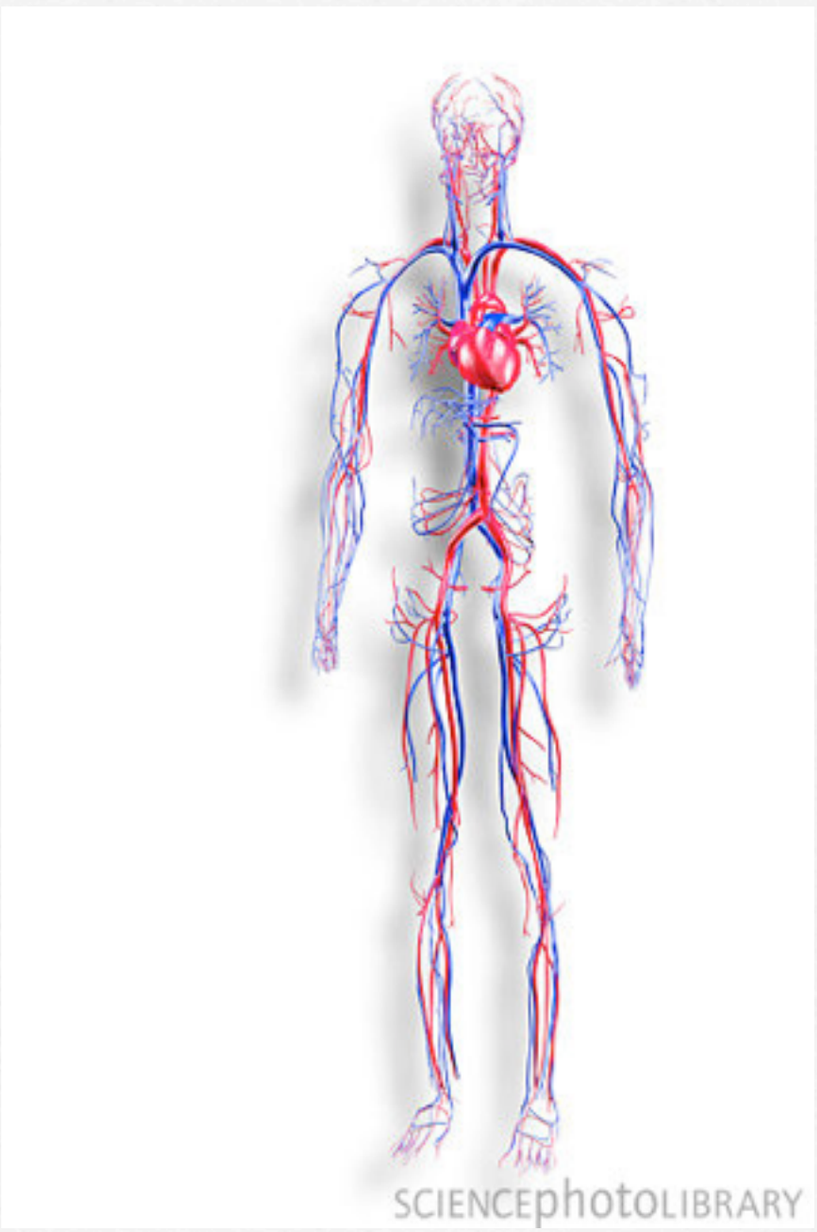
- Recall: Diffusion is slow!
  - (ex. 100 seconds to go 1mm)
- Since gases diffuse, this puts a significant constraint on the body plan of any animal.
- Natural selection has resulted in TWO general solutions.

Here is one of them

- **Solution Two:** A circulatory system that moves fluid between each cell's immediate surroundings and the tissues where exchange with the environment occur.

- found in all other animals





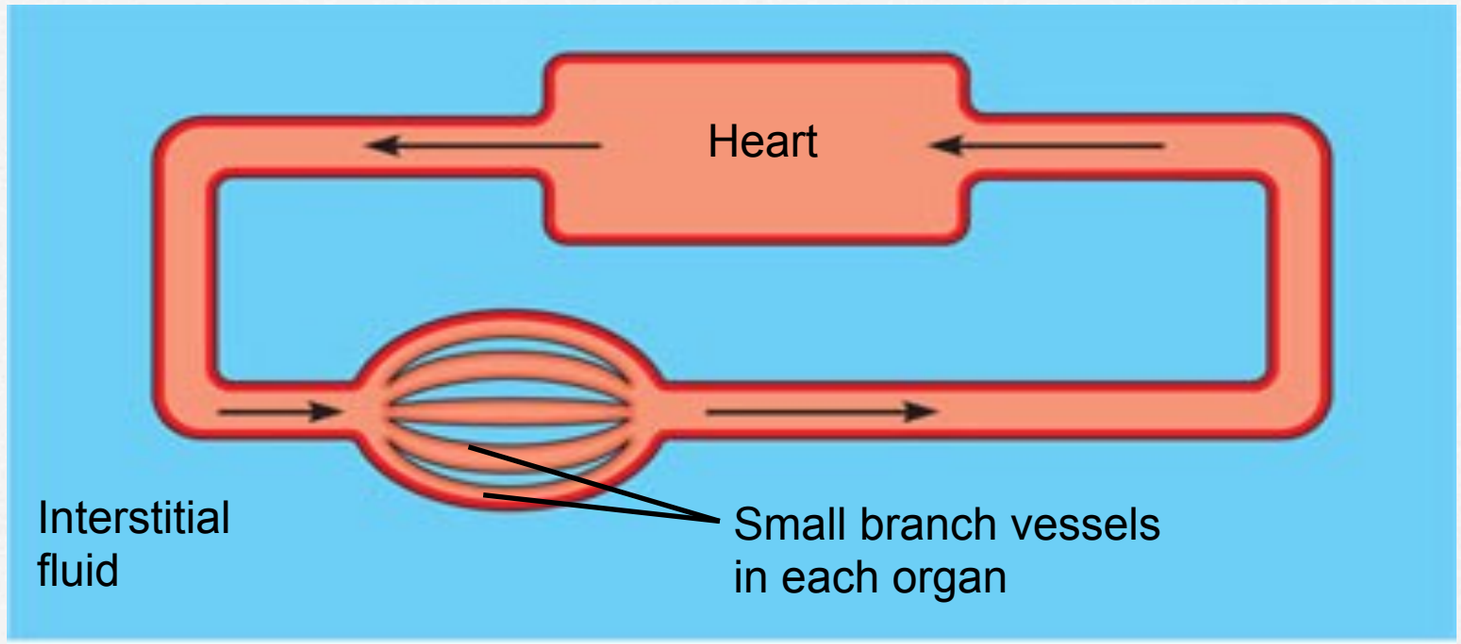
General Properties of Circulatory Systems

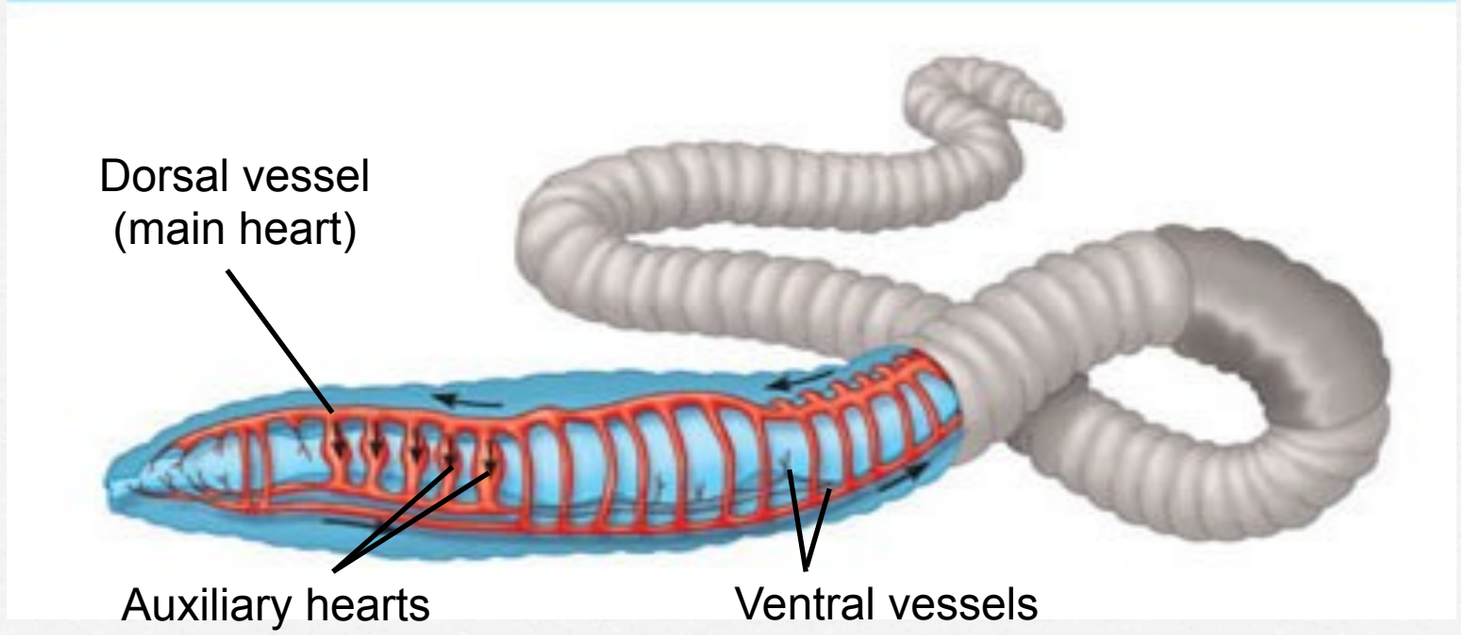
- **A circulatory system has three basic components:**
  - **a fluid, vessels, a pump(s)**
- By moving fluid through the body the circulatory system connects the aqueous surroundings of the cells to the organs that exchange gases (or absorb nutrients, or eliminate waste)
- Several basic types of systems have evolved, each adapted to the constraints imposed by anatomy and environment...
  - open or closed systems
  - number of circuits
  - number of pumps ,organization of pump(s), structure of pump(s)

Closed Circulatory Systems

- **Closed circulatory systems,** a circulatory fluid called *blood* is confined to vessels and is separate from interstitial fluid
  - annelids, cephalopods, all vertebrates
  - Heart(s) pumps blood, blood moves through large vessels which continuously branch into more numerous smaller ones, the very smallest infiltrate organs and tissues, exchange occurs between blood and interstitial fluid and cells, blood returns to the heart.

Closed Circulatory Systems





Organization of Vertebrate Circulatory Systems

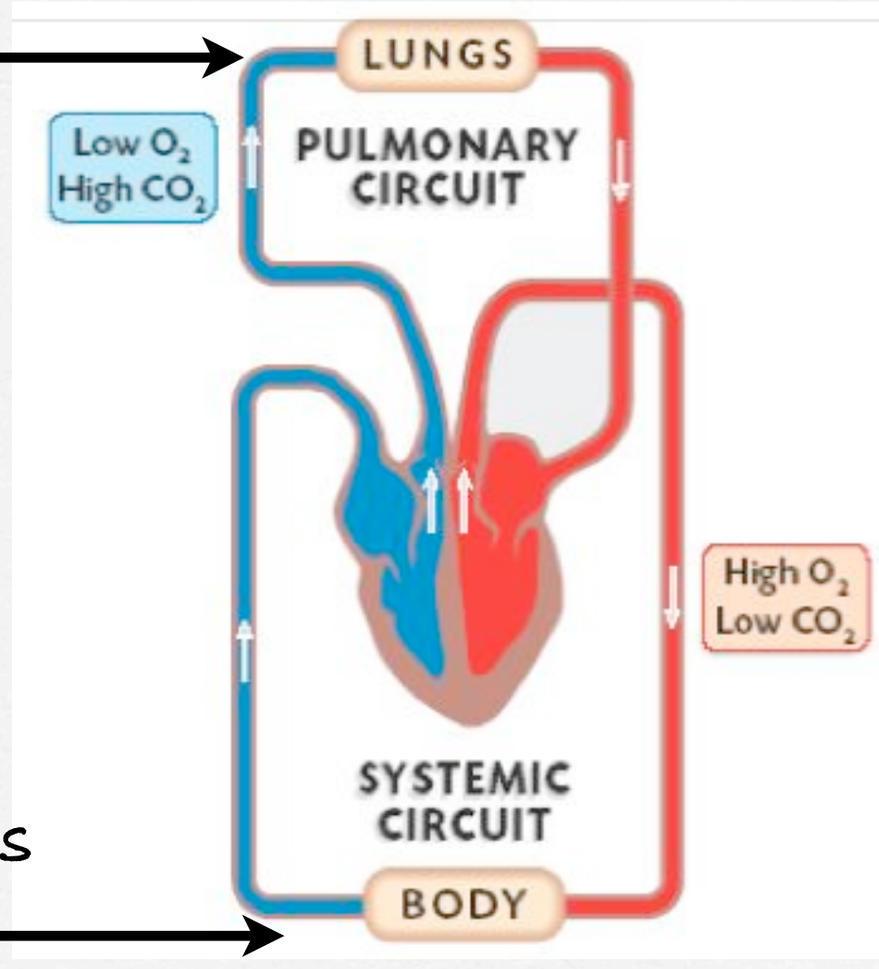
- **Recall a circulatory system has three basic components:**
  - **a fluid, vessels, a pump(s)**
- **The fluid-blood-**fluid component and a cellular component. Although many substances are found within the blood for this unit you only need to remember that oxygen and carbon dioxide are transported carried around the body in this fluid called blood.
- **The pump(s)-heart-**regardless whether an animal has one or more hearts every heart has at least two chambers. Chambers that receive blood are called *atria*. Chambers that pump blood out of the heart are called *ventricles*.

- **The vessels-**form an extensive network that carry blood to and from the heart.
    - The total length of vessels in an adult human is twice the circumference of the earth at the equator! WOW
- **The vessels-**are distinguished by the direction in which they carry blood, not their oxygen content or some other characteristic.
    - *Arteries* carry blood away from the heart and towards capillary beds.
    - *Veins* carry blood away from capillary beds and back to the heart.
    - *Capillaries* are microscopic vessels with very thin (one cell thick) porous walls. *Capillaries* infiltrate every tissue of the body and comes within a few cell diameters of every cell in the body. Gases are exchanged through cell walls of capillaries, into interstitial fluid and finally into each cell and vice versa.

Double Circulation

- The heart consists of two pumps one for each circuit.
  - amphibians, reptiles, mammals

Carbon dioxide diffuses out of blood, oxygen diffuses into blood

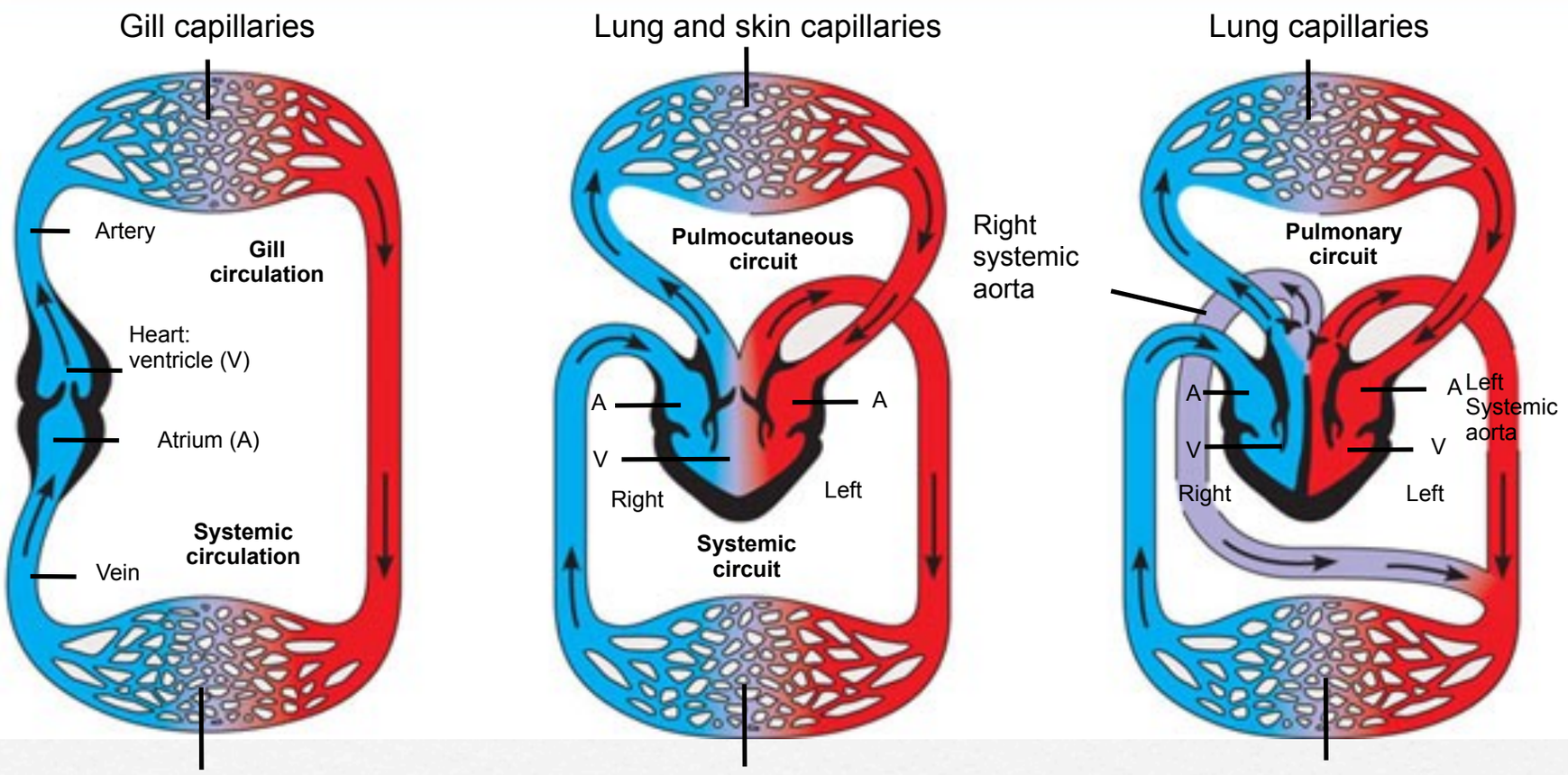


Carbon dioxide diffuses into blood, oxygen diffuses out of blood

The two pumps provide vigorous flow throughout the body. When blood moves through the capillary beds of lungs it loses much pressure however blood returns to the heart's second pump which reestablishes a hydrostatic pressure

Vertebrate Circulatory Systems

FISHES	AMPHIBIANS	REPTILES (EXCEPT BIRDS)	MAMMALS AND BIRDS



"In Summary"

- Animals can either have a body plan that puts every cell in contact with its environment so that gas exchange occurs a rate to sustain life OR...
- Animals can use a circulatory system to deliver oxygen to every cell and remove carbon dioxide waste from every cell.
- BUT How does the organism as a whole get oxygen and get rid of carbon dioxide?
  - Answer...Respiratory Systems exchange gas between the outside environment and the circulatory system.

Gas Exchange Occurs Across Specialized Respiratory Surfaces

- **Gas Exchange or Respiration** (not to be confused with cellular respiration) is the uptake of molecular oxygen from the environment and the discharge of carbon dioxide to the environment.

Partial Pressure Gradients in Gas Exchange

- To understand gas exchange we must understand partial pressures.
- **Partial Pressure** is simply the pressure exerted by a particular gas in a mixture of gases.
  - Ex. the atmosphere at sea level exerts a force equal to 760mm Hg, oxygen makes up 21% of the atmosphere thus (760mm Hg) (0.21)= 160 mm Hg, the partial pressure oxygen!

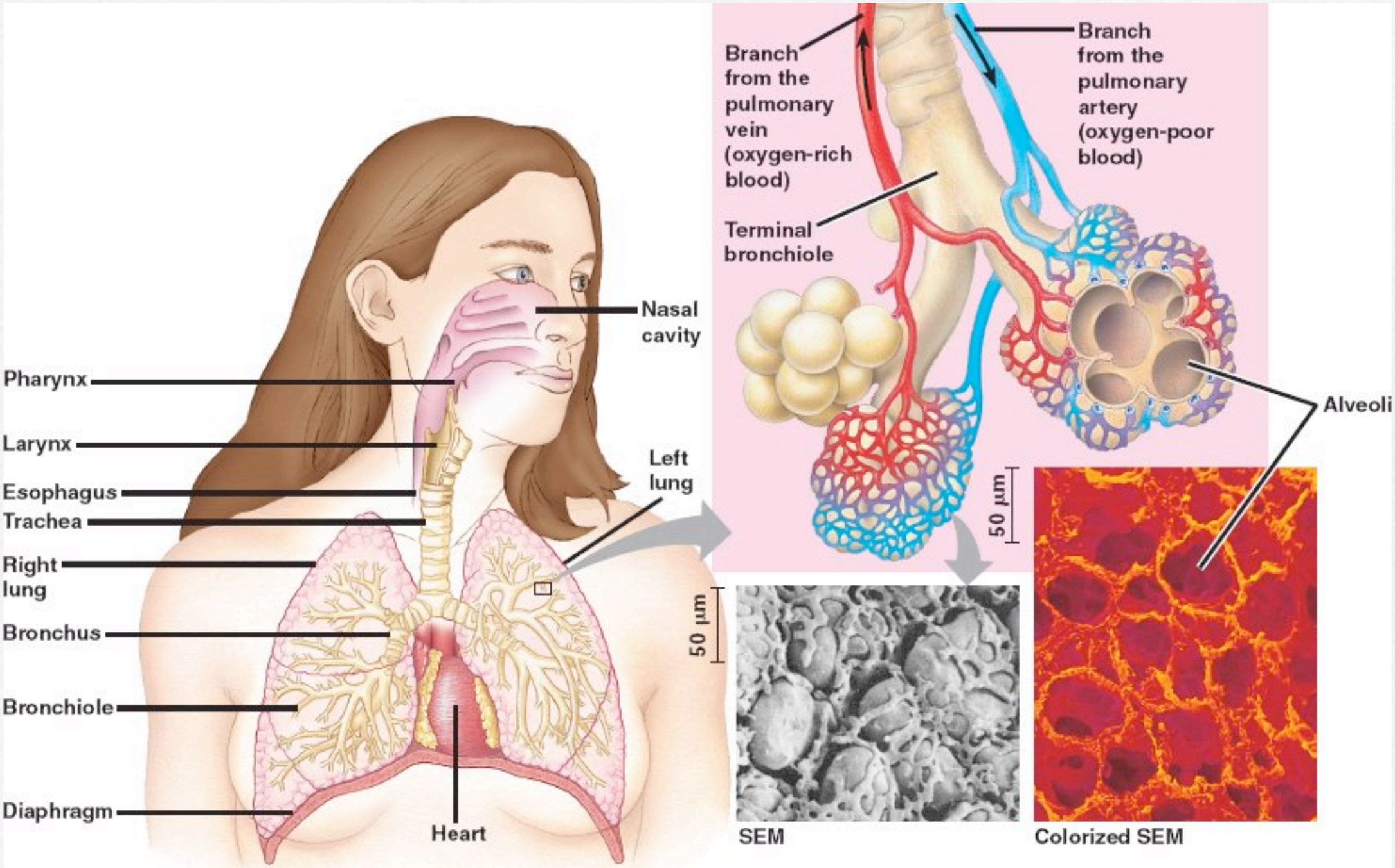
Once we know the partial pressures of the gas at the exchange surface we can easily predict its net diffusion.

- **Gases always diffuse from a region of higher partial pressure to a region with lower partial pressure!**

Lungs

- **Lungs** do not branch throughout the entire body, instead they are localized infoldings of the body surface
- **Lungs-** are respiratory organs where gas exchange between the outside world and the circulatory system take place.
  - because lungs do not bring gas to every cell the circulatory is required to connect the lungs with all cells of the organism.
  - lungs are found in open circulatory systems such as spiders and snails
  - lungs are found in closed systems as well, all vertebrates that lack gills use lungs instead
    - Variation does exist among lungs!

Mammalian Respiratory System



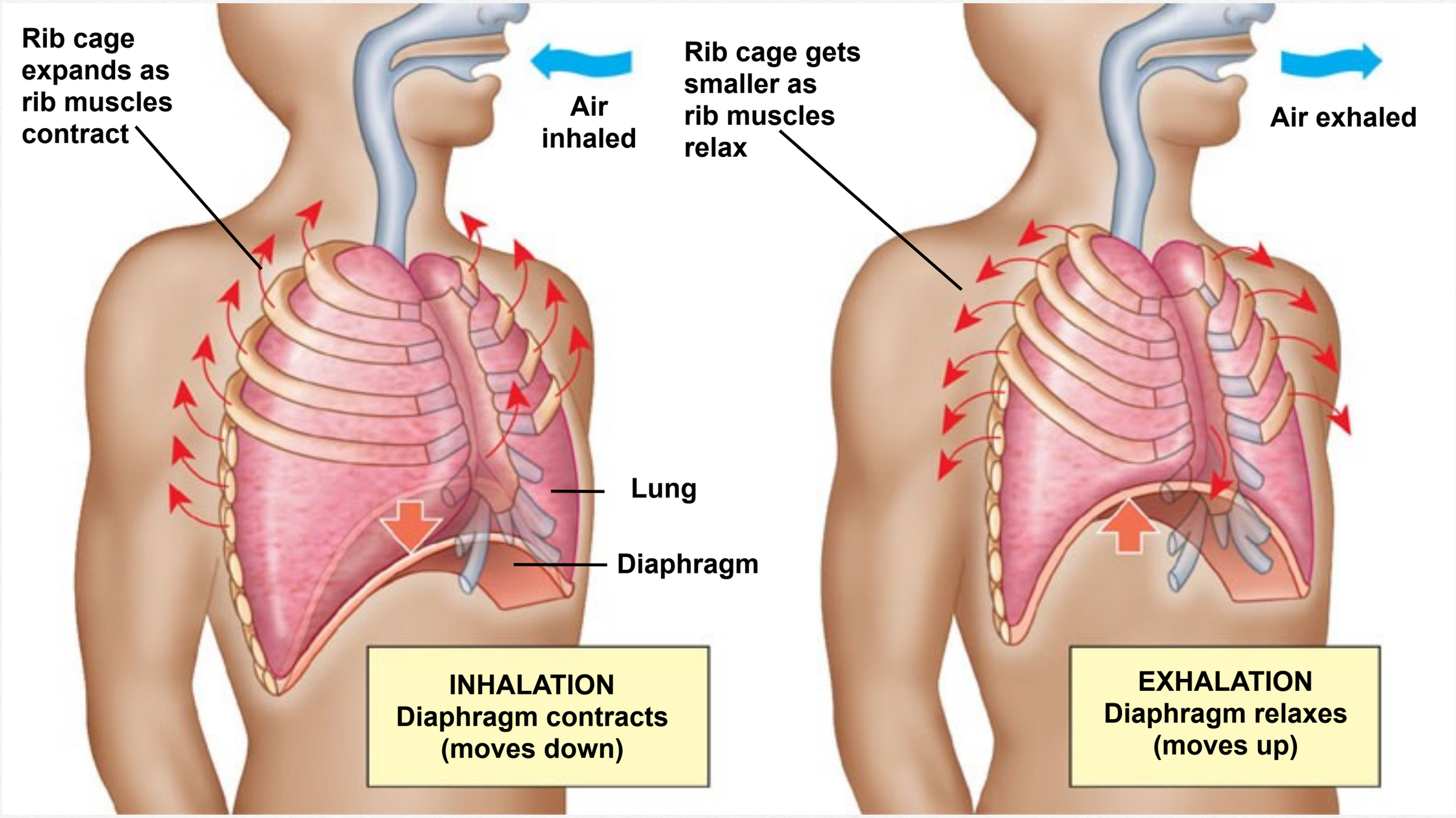
Breathing Ventilates the Lungs

- **Breathing,** the alternating inhalation and exhalation of air, ventilates the lungs.
- *Ventilation* maintains high O_2 and CO_2 concentrations at the gas exchange surface.
    - A variety of breathing mechanisms have evolved!
    - We will explore, amphibian, bird and mammal adaptations

Mammal Breathing

- Mammals use **Negative Pressure Breathing,** they pull rather than push air into their lungs.
    - *1. muscles contract and increase volume of thoracic cavity*
    - *2. as volume increases, pressure drops lower than outside air*
    - *3. air rushes from higher outside pressure to lower inside pressure*
    - *4. air moves through nostrils and mouth, down trachea, to alveoli*
    - *5. muscles relax and decrease volume of thoracic cavity*
    - *6. as volume decreases, pressure rises higher than outside air*
    - *7. air moves out of lungs to outside*
        - **inhalation is active, exhalation is passive*

Mammal Breathing



Adaptations for Gas Exchange Include Pigments that Bind and Transport Gases

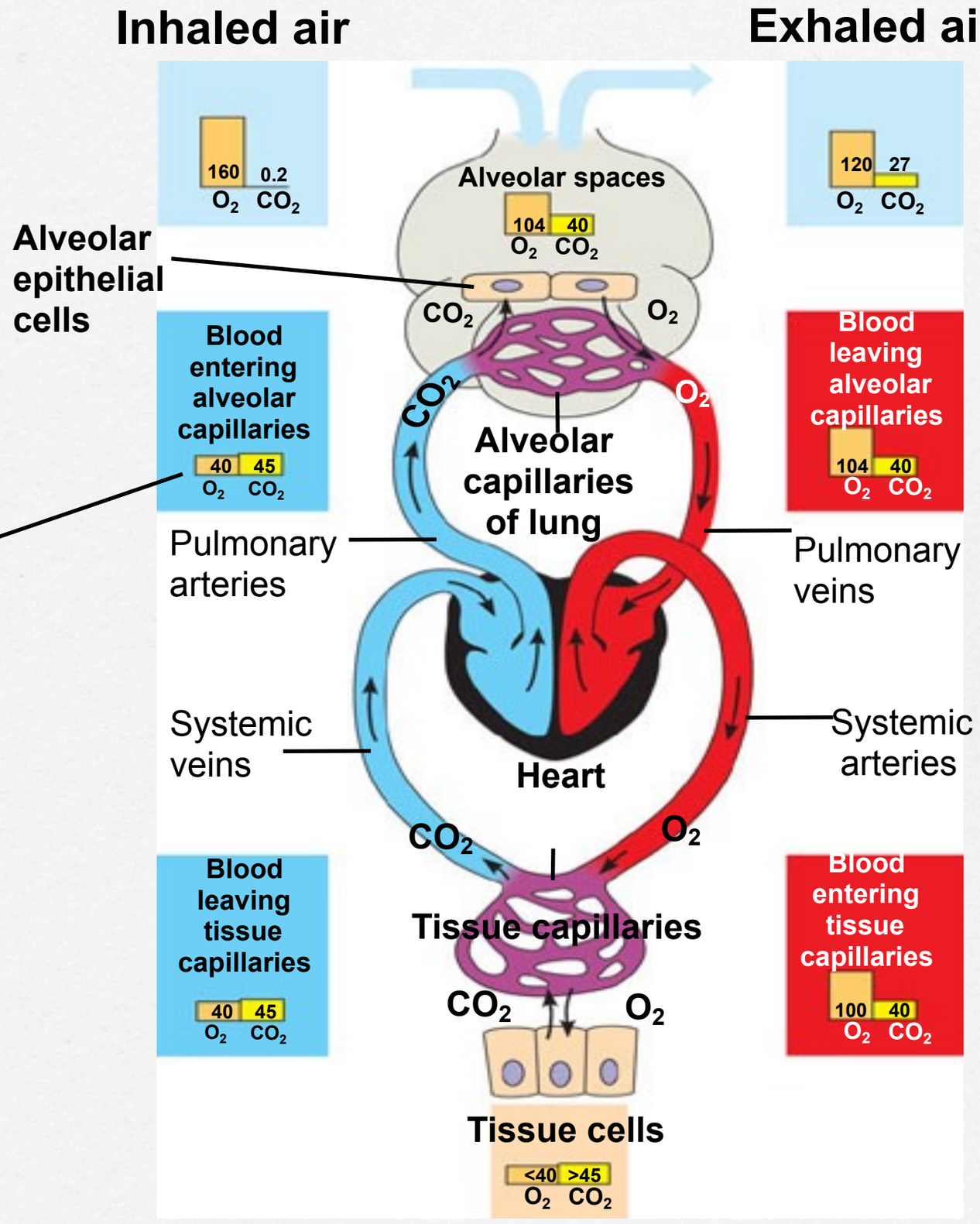
- High metabolic demands of many animals necessitate large quantities of O_2 and CO_2.
- Respiratory pigments facilitate this exchange through their interaction with O_2 and CO_2.

Coordination of Circulation and Gas Exchange

All numbers in orange and yellow boxes are partial pressures in mm/Hg

Coordination of Circulation and Gas Exchange

All numbers in orange and yellow boxes are partial pressures in mm/Hg



Respiratory Pigments

- The low solubility of O_2 in water poses a problem for animals that rely on a circulatory system to deliver oxygen.
  - Case in Point:
    - Human requires 2L of O_2 per minute of intense exercise
    - Only 4.5 ml of O_2 can dissolve into 1L of blood in the lungs (at standard temp and pressure)
    - Without the help of pigments the heart would need to pump 555L of blood per minute!
- **Most animals transport their O_2 bound to proteins called *respiratory pigments*.**

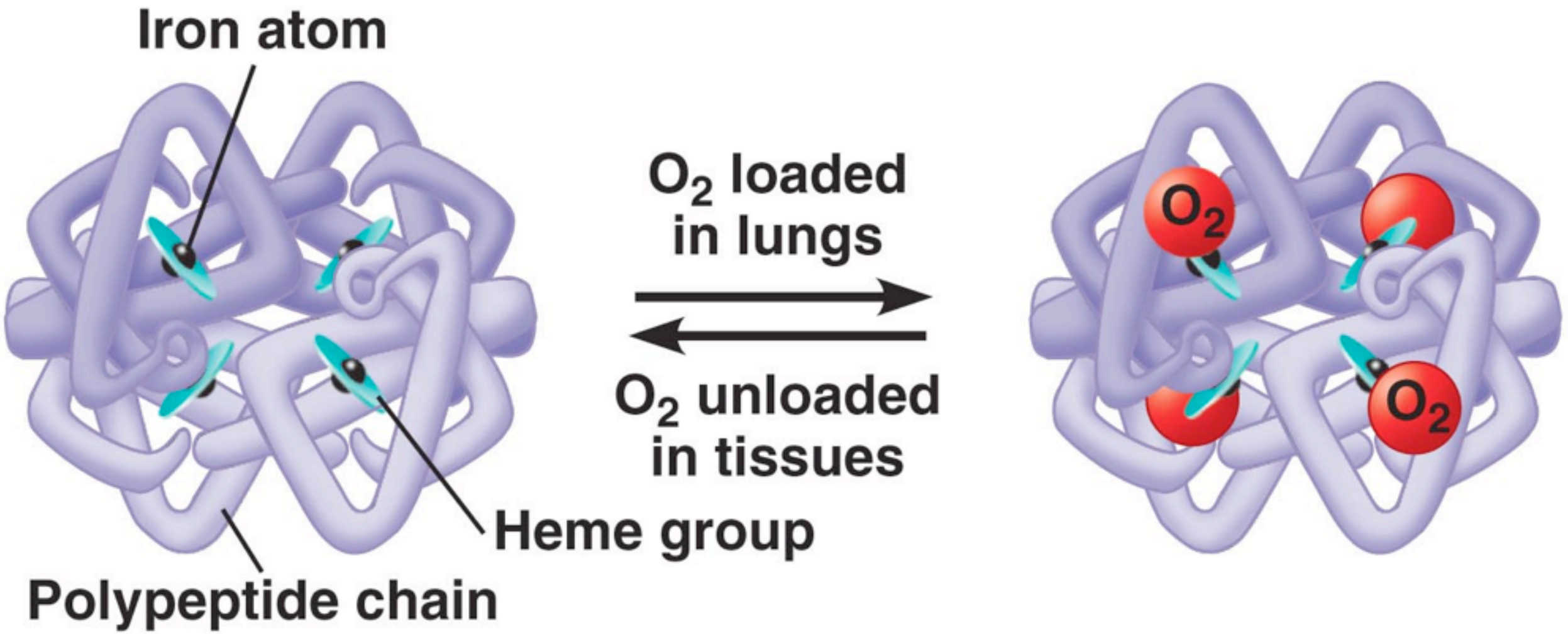
Respiratory Pigments

- ***Respiratory pigments*** greatly increase the amount of O_2 that the circulatory fluid can carry.
  - Same Case in Point: (with pigments)
    - Human requires 2L of O_2 per minute of intense exercise
    - Now 200 ml of O_2 can dissolve into 1L of blood in the lungs (at standard temp and pressure)
    - Without the help of pigments the heart would need to pump 12.5L of blood per minute!
- **A variety of *respiratory pigments* have evolved.**

Respiratory Pigments

- ***Hemoglobin;*** a protein with 4 subunits with iron molecules that bind oxygen.
  - each subunit has 1 iron molecule that carries 1 oxygen molecule
  - thus 1 hemoglobin protein carries 4 oxygen molecules
  - found in almost all vertebrates and many invertebrates
  - has a red color

Hemoglobin



Nervous & Muscular

Main Idea

- ***Sensing and consequently Responding to the environment is an absolute necessity for all organisms.***

- You might have heard that all organisms can sense some kind(s) of environmental stimuli.

- You might also recall that many responses occur at the cellular level, but again this unit will focus on responses at the organismal level.

INFORMATION PROCESSING

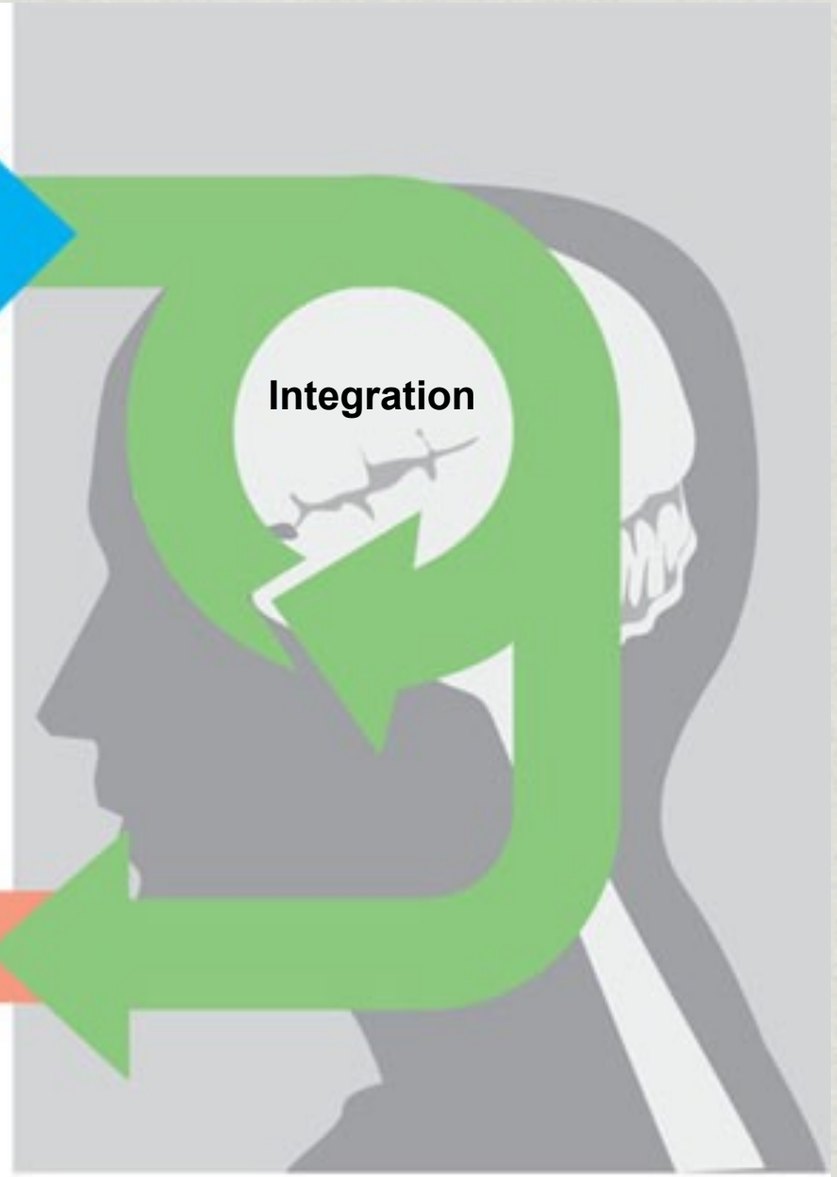
Sensor

Effector

Sensory input

IN GENERAL

Motor output



Peripheral nervous system (PNS)

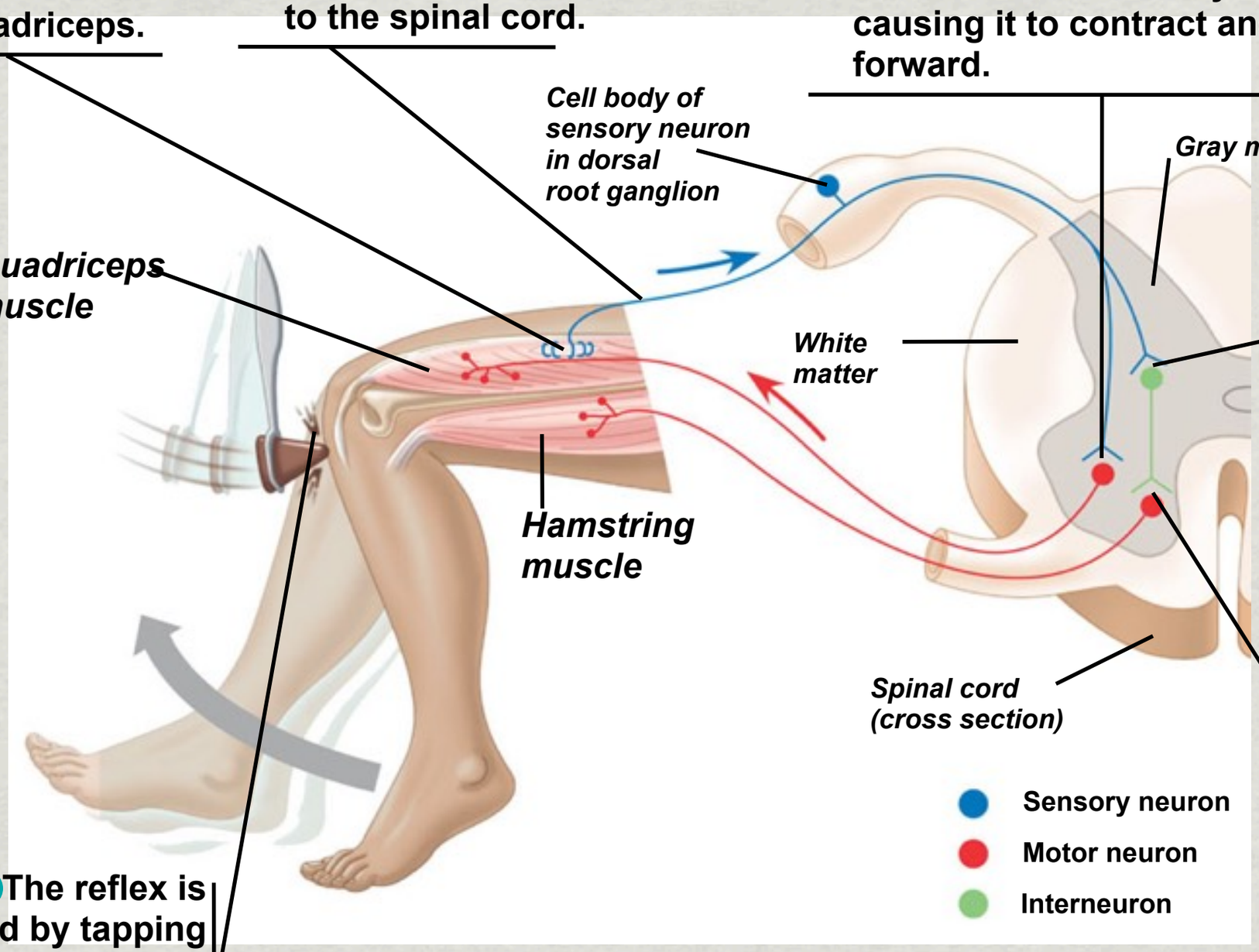
Central nervous system (CNS)

INFORMATION PROCESSING

2 Sensors detect a sudden stretch in the quadriceps.

3 Sensory neurons convey the information to the spinal cord.

4 The sensory neurons communicate with motor neurons that supply the quadriceps. The motor neurons convey signals to the quadriceps, causing it to contract and jerking the lower leg forward.



5 Sensory neurons from the quadriceps also communicate with interneurons in the spinal cord.

1 The reflex is initiated by tapping the tendon connected to the quadriceps (extensor) muscle.

6 The interneurons inhibit motor neurons that supply the hamstring (flexor) muscle. This inhibition prevents the hamstring from contracting, which would resist the action of the quadriceps.

A SPECIFIC EXAMPLE

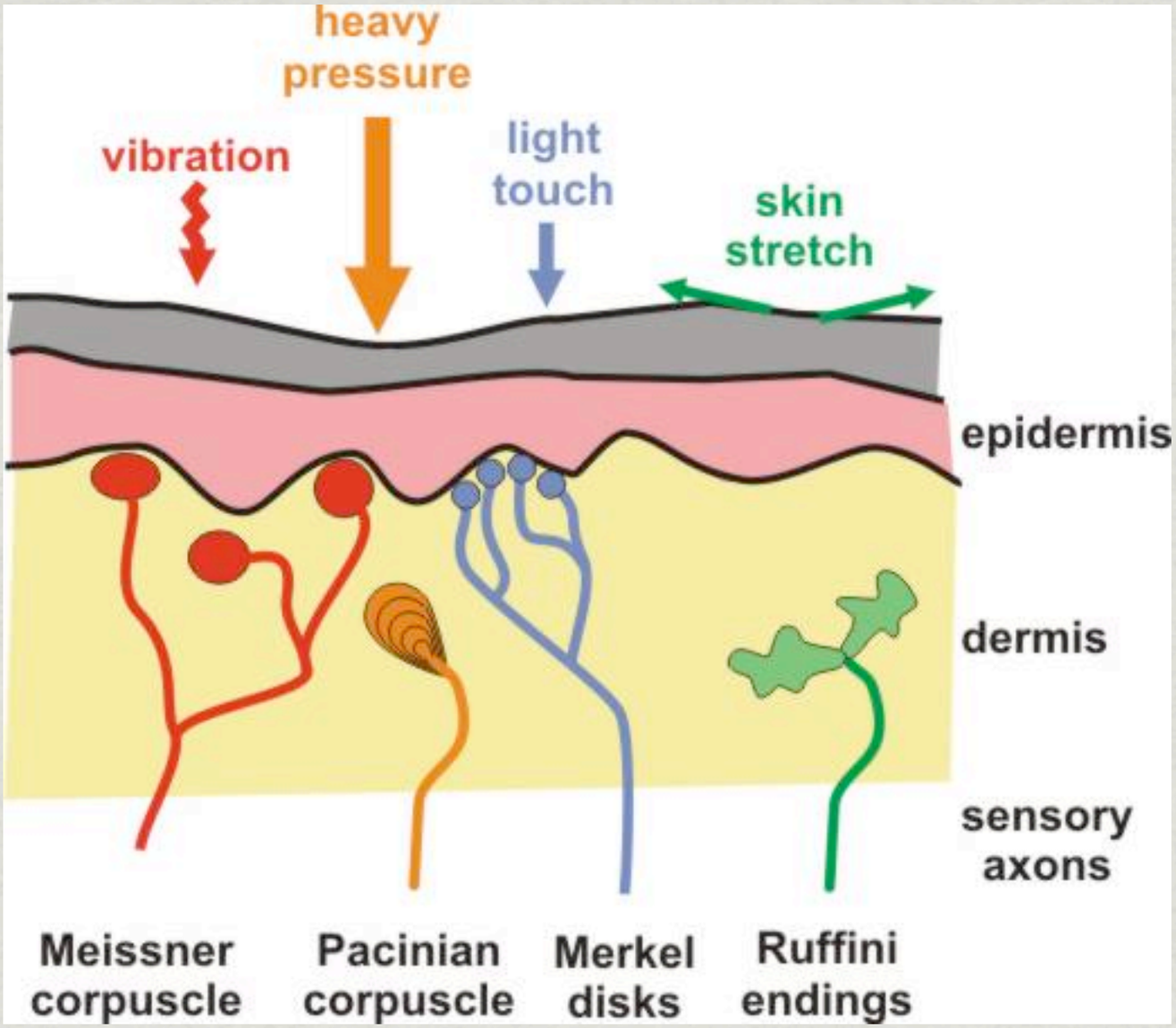
SENSING STIMULI

Mechanoreceptors

- Sense physical deformation caused by forms of mechanical energy such as pressure, touch, stretch, motion and sound

Mechanoreceptors

- Sense physical deformation caused by forms of mechanical energy such as pressure, touch, stretch, motion and sound



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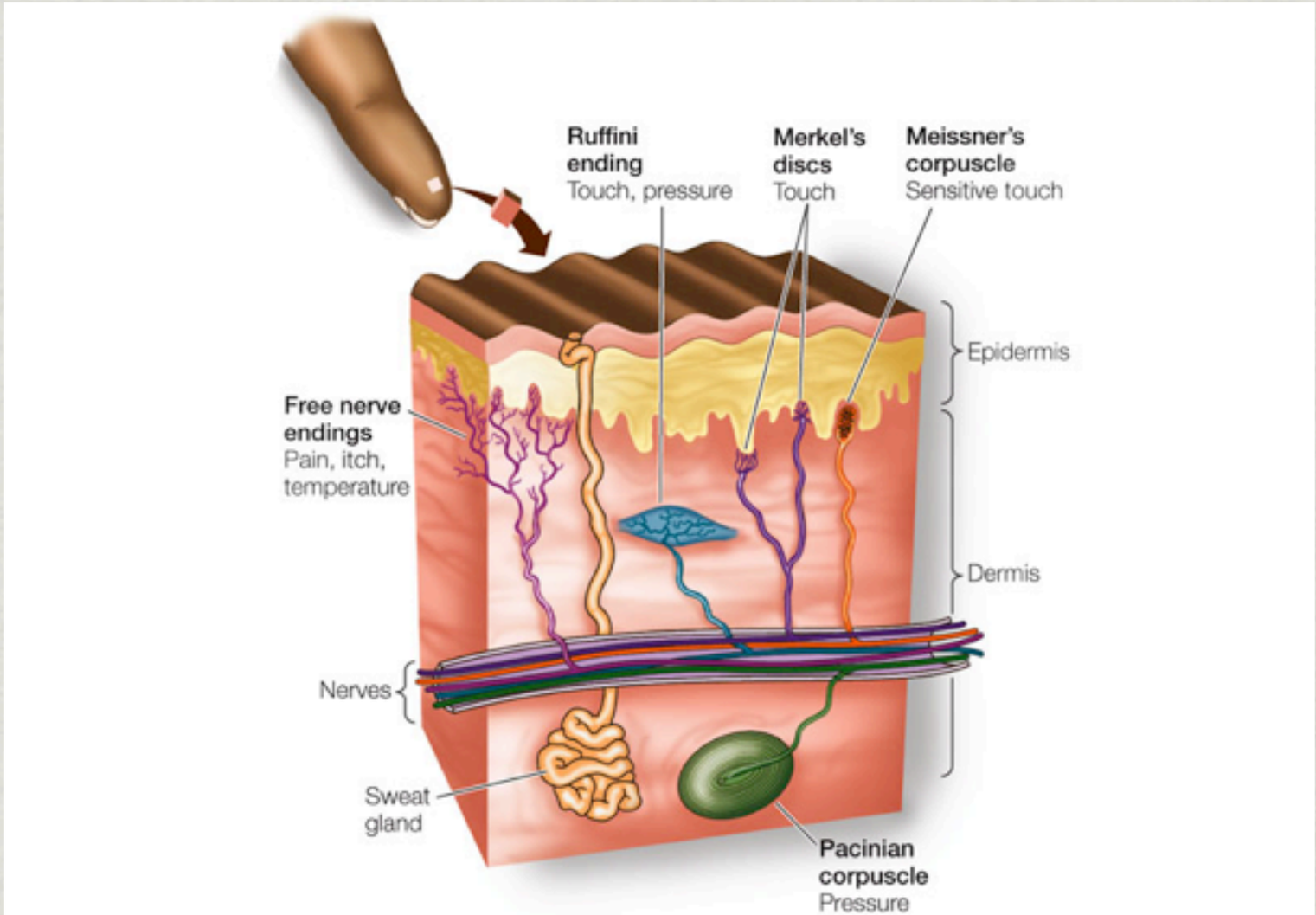
Mechanoreceptors

- Sense physical deformation caused by forms of mechanical energy such as pressure, touch, stretch, motion and sound



***LIFE 8e*, Figure 45.6**

Chemoreceptors

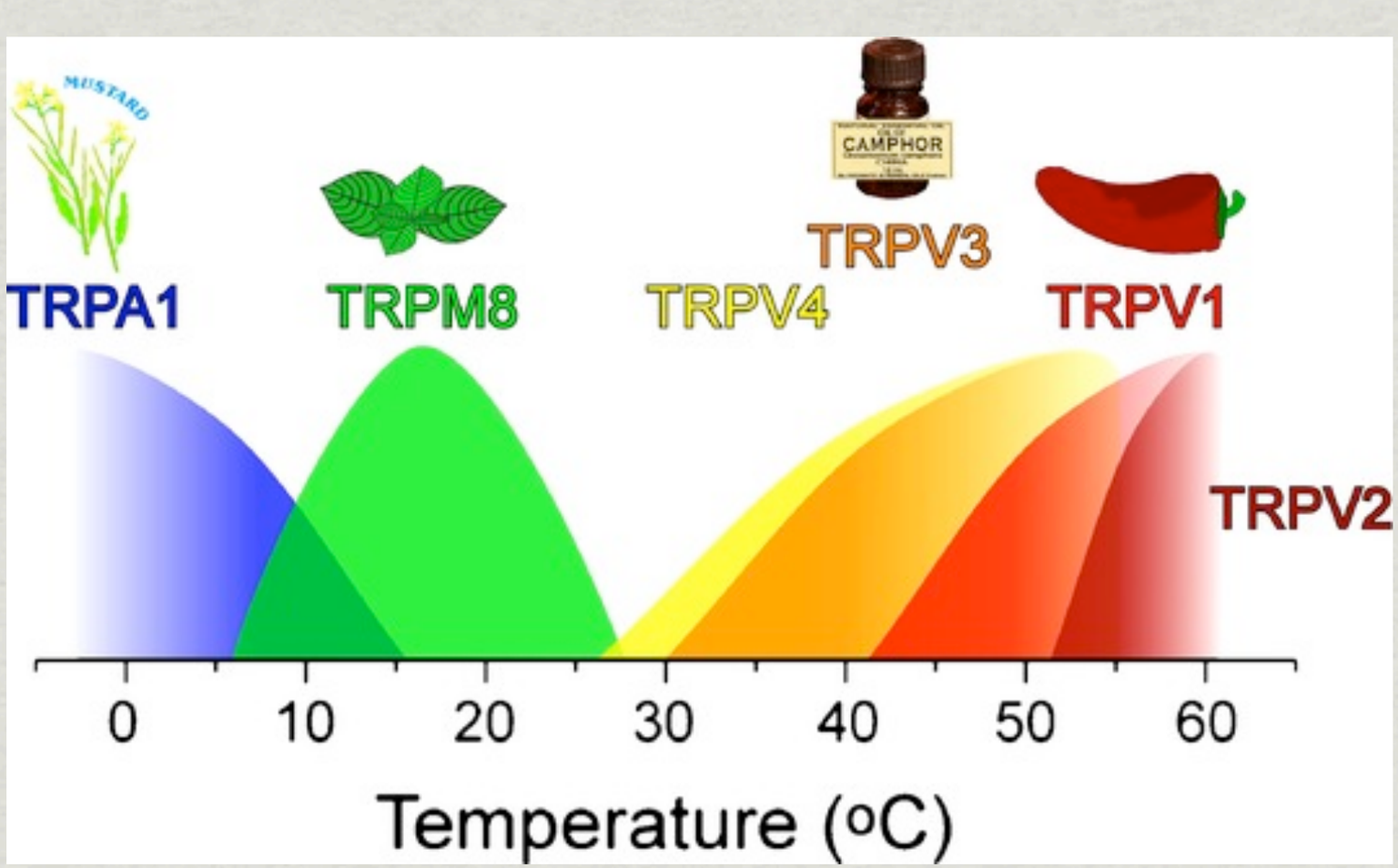
- Transmit information about specific molecules or total solute concentration.
  - Osmoreceptors in brain detect concentration of blood and generate perception of thirst if blood in concentrated
  - Many organisms have receptors for specific molecules such as oxygen, carbon dioxide, glucose and amino acids.

Electromagnetic Receptors

- Detect various forms of electromagnetic energy such as light, infrared, UV, electricity and magnetism.
  - Snakes detect infrared radiation.
  - Pigeons detect magnetic fields.
  - Platypus detects electric fields.

Thermoreceptors

- Detect heat and cold.
  - Mammals have different kinds of thermoreceptors that belong to a family of receptors called “TRP’s”
  - Each TRP receptor detects a different temperature range.



Photoreceptors

- Detect wavelengths of visible light: Roy G. Biv
  - Rods and cones detect light in vertebrates.

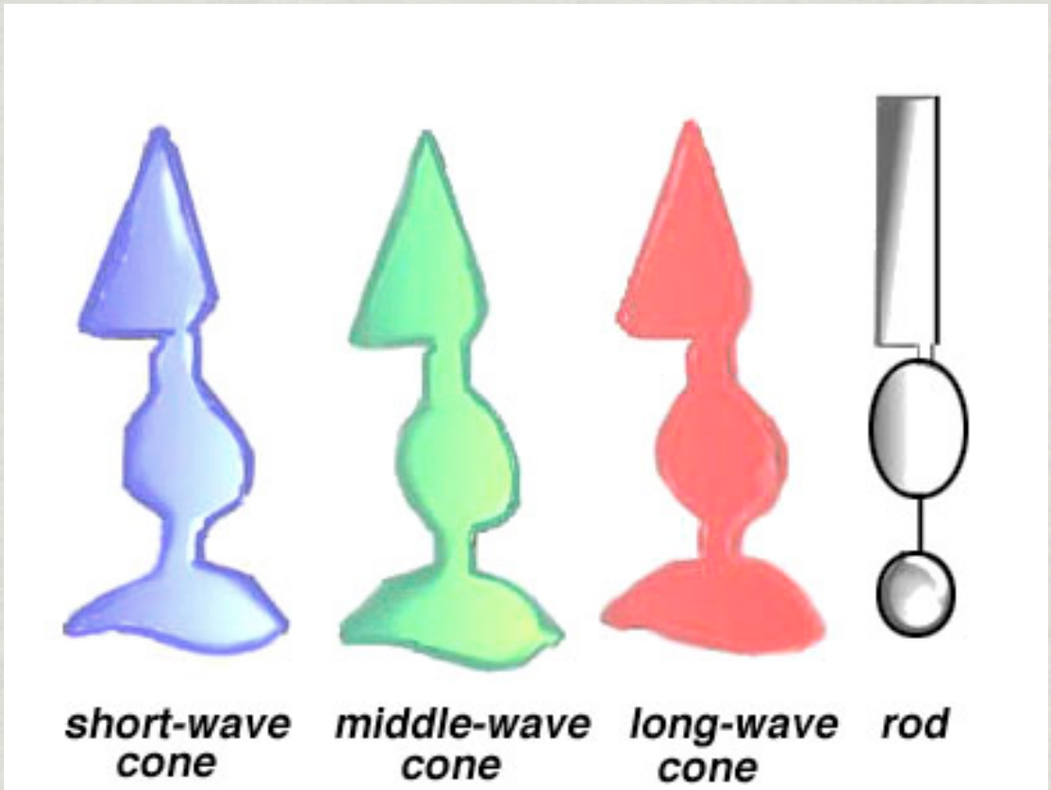


Fig. 13. There are four photoreceptor types in the human retina. Short-wavelength cones (blue), medium wavelength cones (green), long wavelength cones (red) and rods.

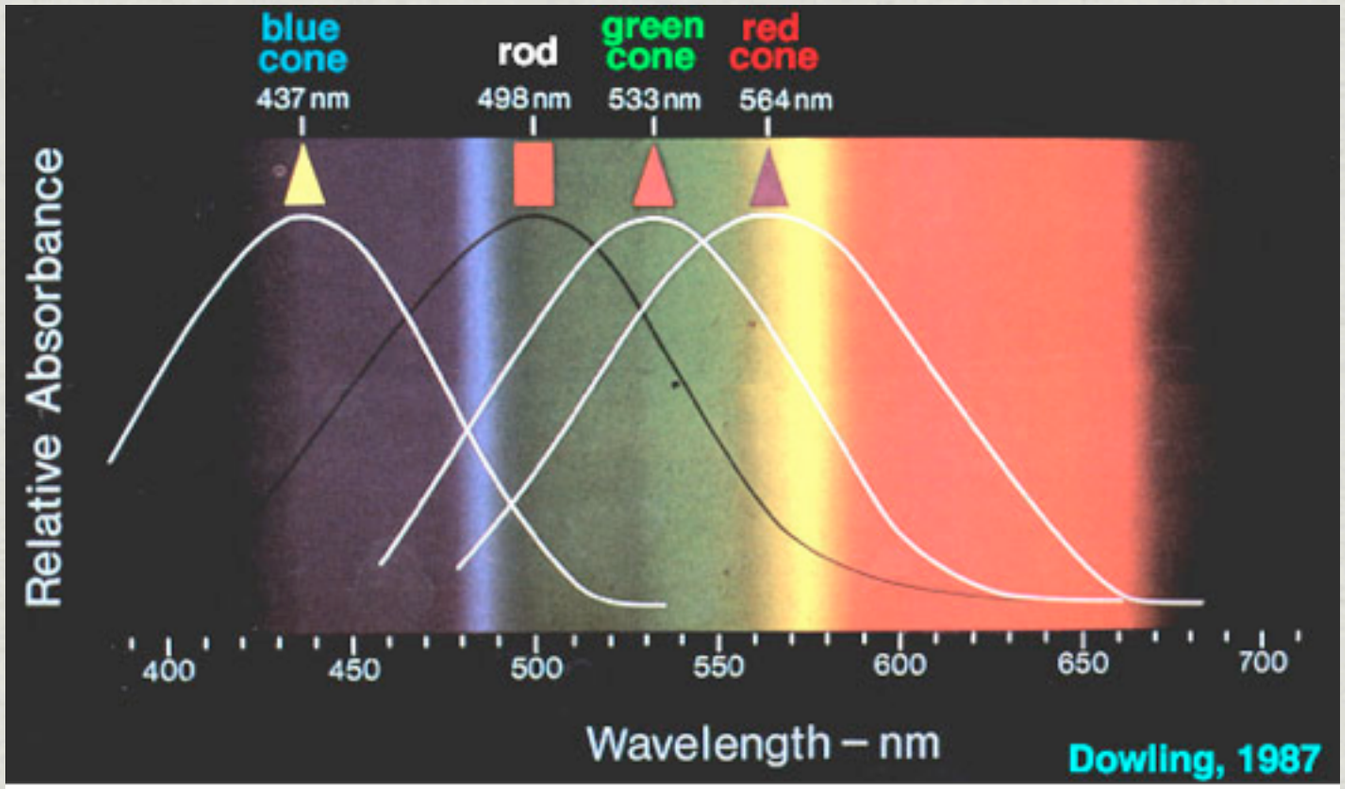


Fig. 14.The peak spectral sensitivities of the the 3 cone types and the the rods in the primate retina (Brown and Wald, 1963). From Dowling's book (1987).

Nociceptors (Pain Receptors)

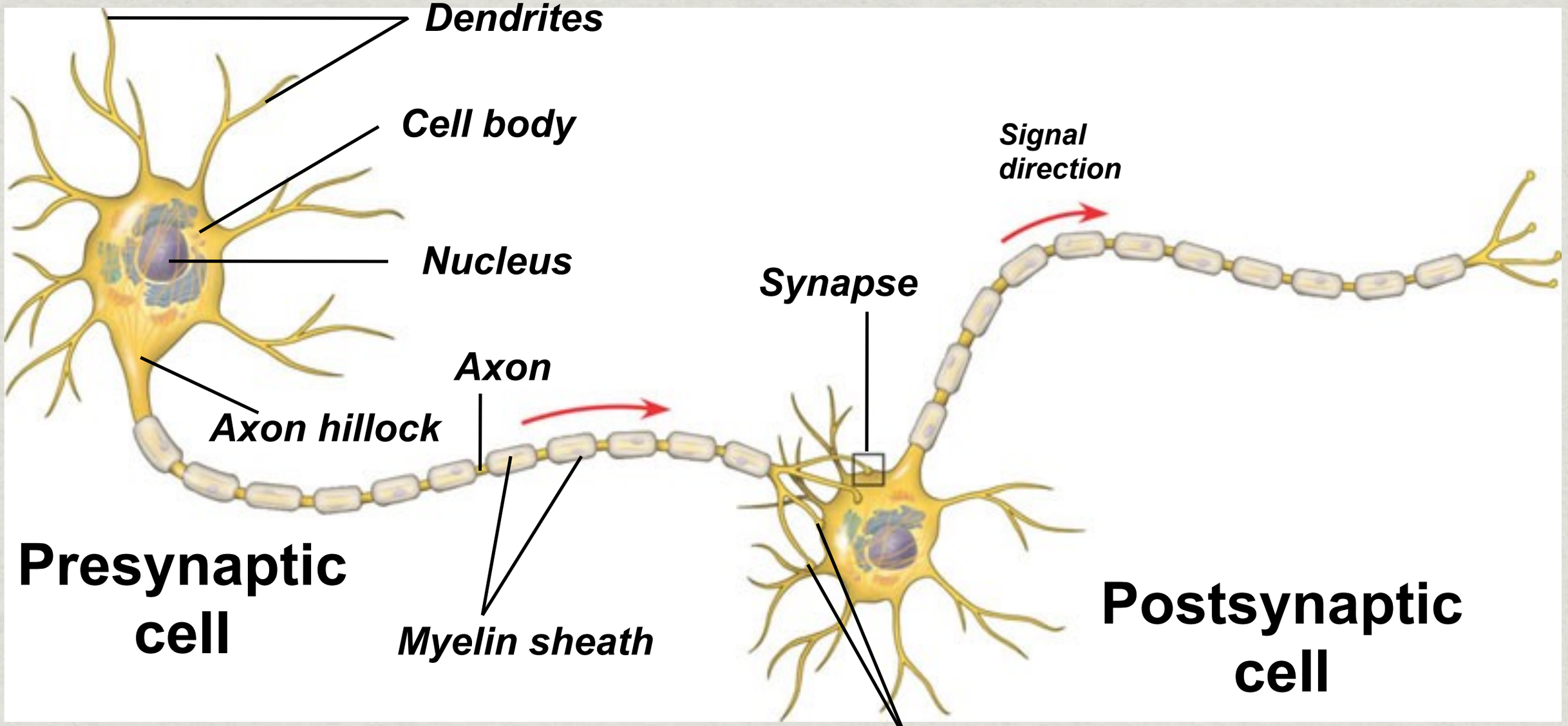
- Detect extremes: temperature, pressure, heat or chemicals.
  - Many of the other receptors can act as a pain receptors in cases of extreme stimuli.
- Pain is an important defensive trigger as it cause the organism to withdraw from danger

NEURONS: Structure & Function

- **Neurons are the functional units of nervous systems.**
  - **Neurons transmit signals from one location in the body to another .**
  - **The most striking feature about these cells are the fiber like extensions called projections (dendrites & axons)**
- As you might expect neuron structure varies according to its specific function but for this particular class we will.

Transmitting the Message

Neuron: STRUCTURE



Neuron: STRUCTURE

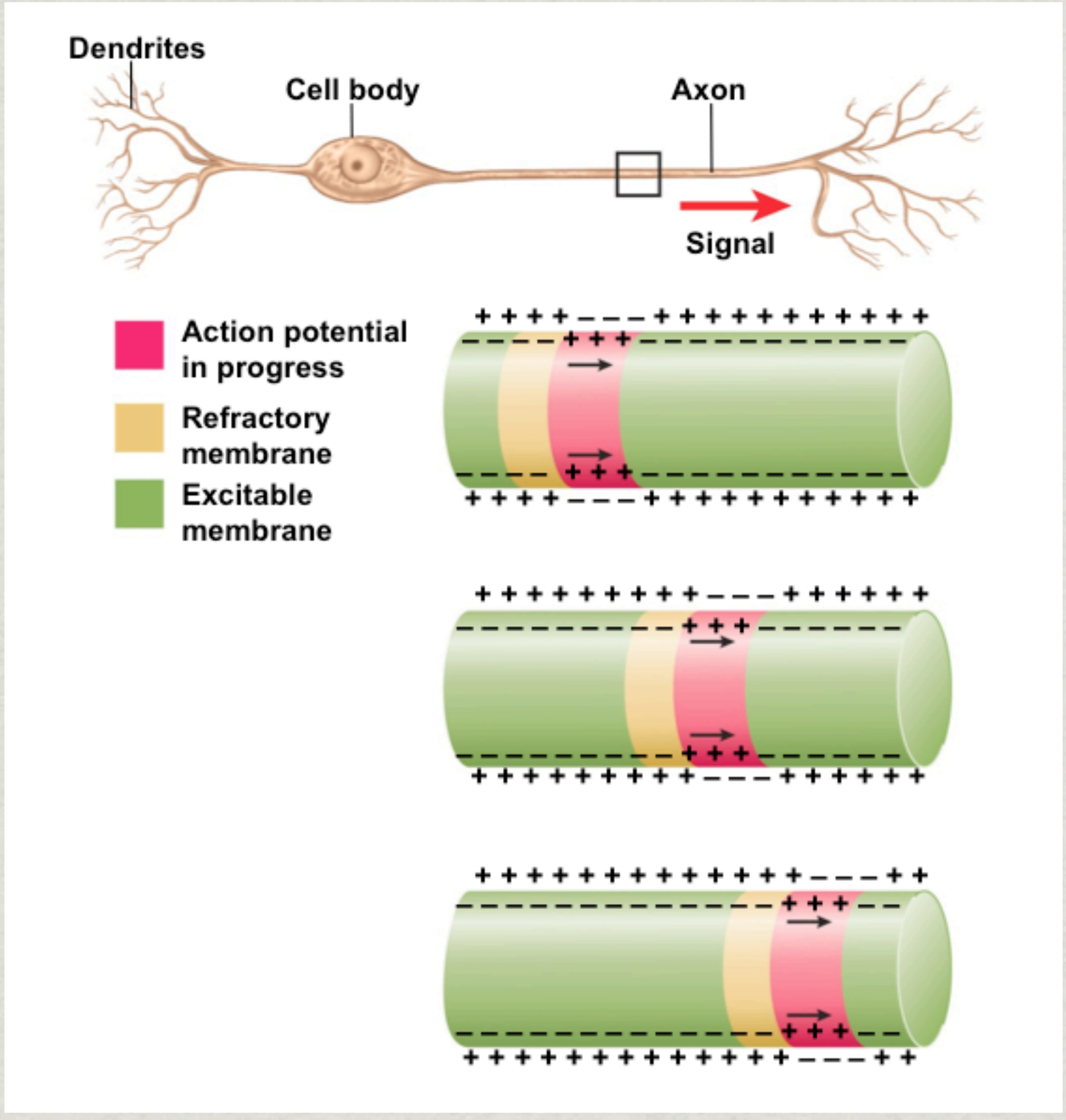
- **Dendrite(s)-** receive incoming information
- **Cell Body-** contains nucleus and other organelles
- **Axon Hillock-** where cell body meets axon, generates electrical impulses
- **Axon-** conducts incoming information to the end of the neuron
- **Myelin Sheath-** insulating layer around axon, increases impulse speed
- **Synaptic Terminal(s)-** relays information to target cell
- **Synapse-** site where synaptic terminal meets target cell

Neuron: FUNCTION (action potentials)

- **Action potentials exist in a neuron when it IS sending impulses.**
- **It results in a rapid and dramatic change in ion concentrations.**
- **Voltage gated channels are responsible for the generation of action potentials.**
- **Action potentials do not exist unless threshold values are reached.**

Neuron: (action potential conduction)

This example shows a neuron that is NOT myelinated!

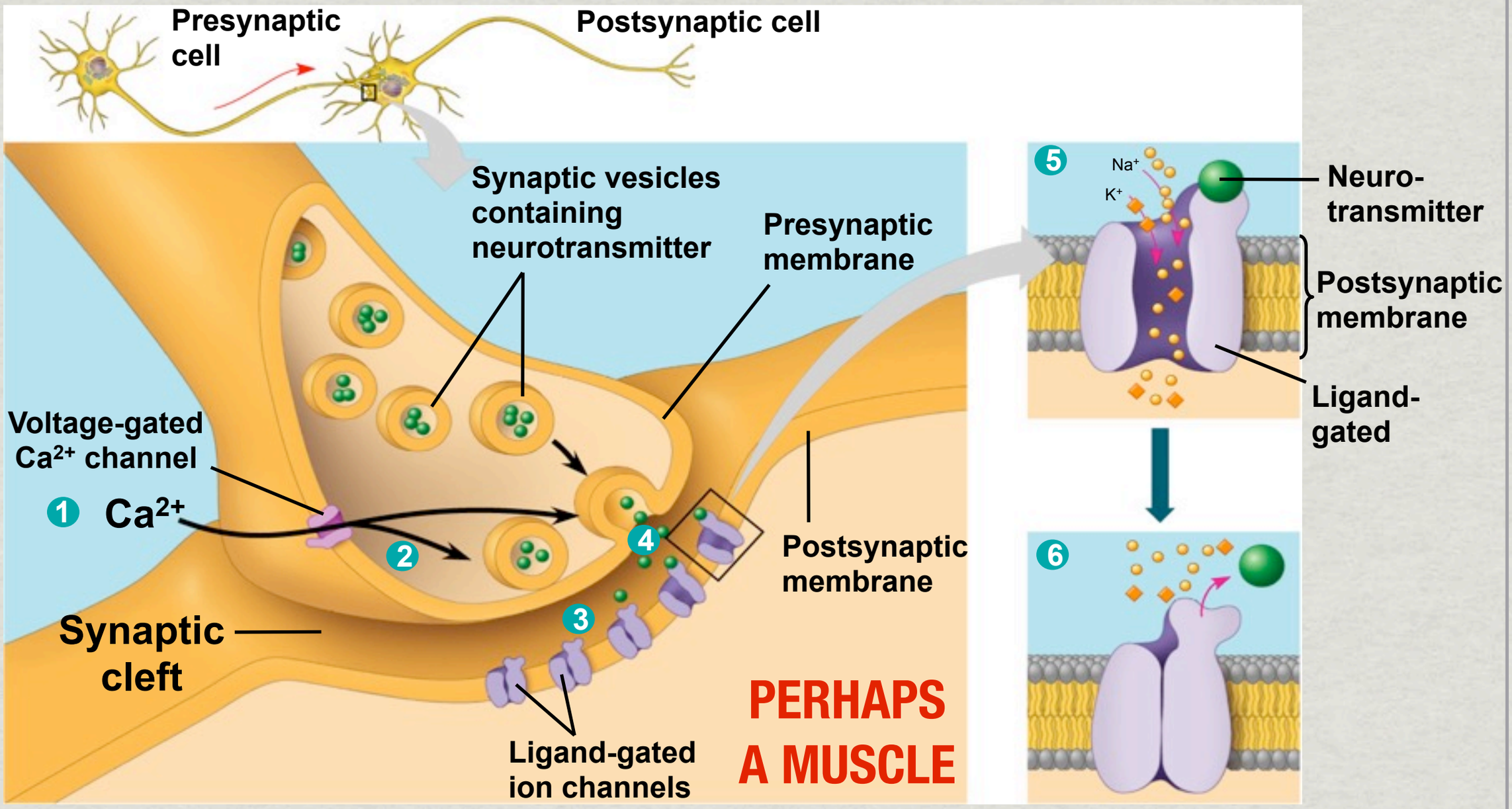


“Talking” to the Muscles

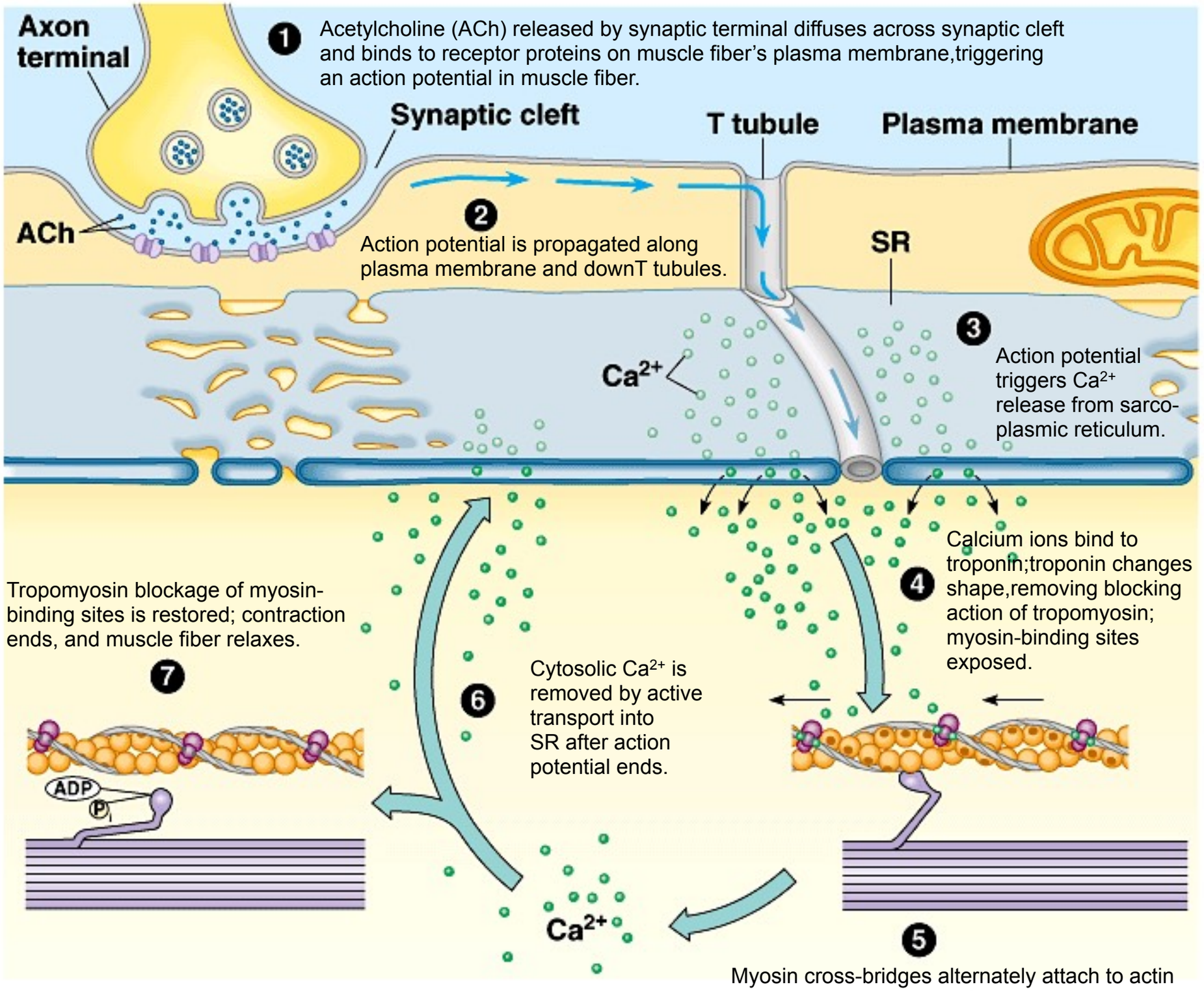
Neuron: FUNCTION (synaptic transmission)

- **Nerve cells communicate with other cells at synapses.**
- **An electric synapse occurs where the electrical impulse flows from one nerve cell through a gap junction into another nerve cell.**
- **A chemical synapse occurs where the electrical impulse reaches the end of one nerve cell, is converted to a chemical message that binds to an effector cell.**
- **Effector cells include other nerves, muscles or glands**
- **This type of synapse is more common.**

Neuron: FUNCTION (synaptic transmission)



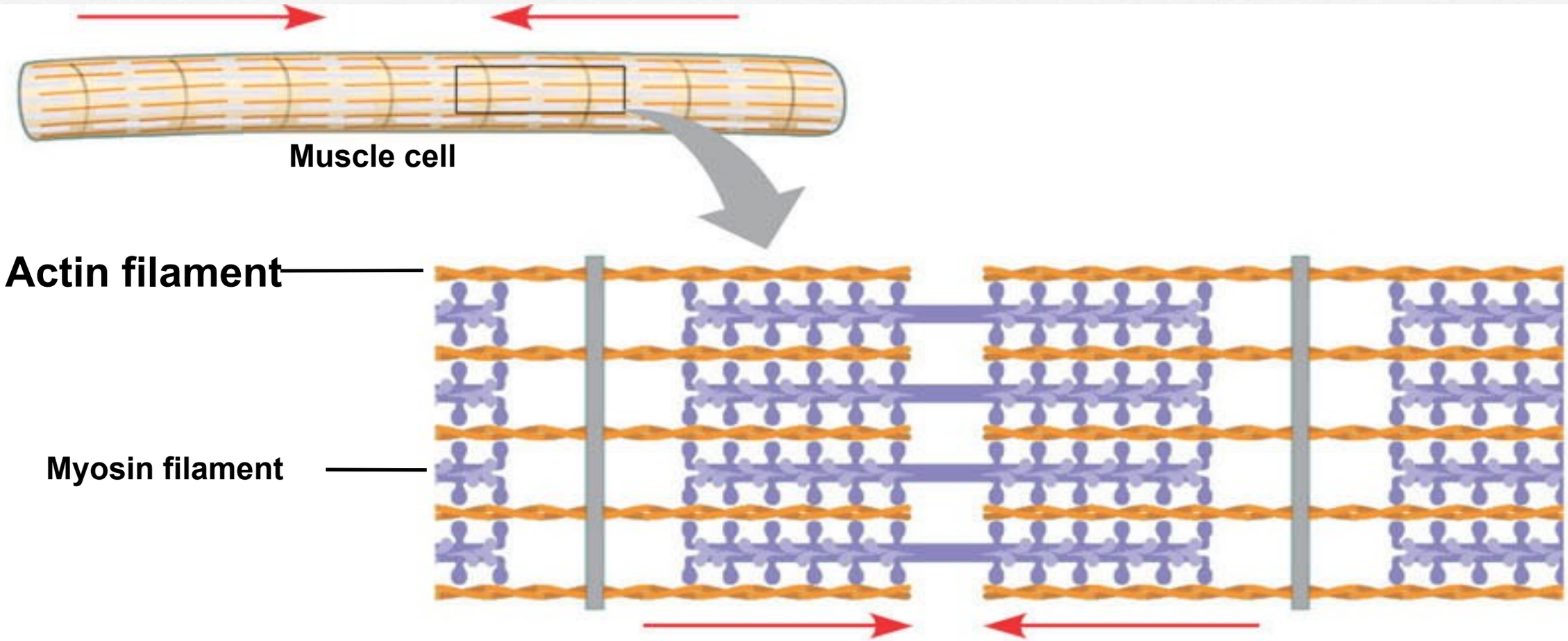
Skeletal Muscle Contraction Sequence



How Muscles Contract

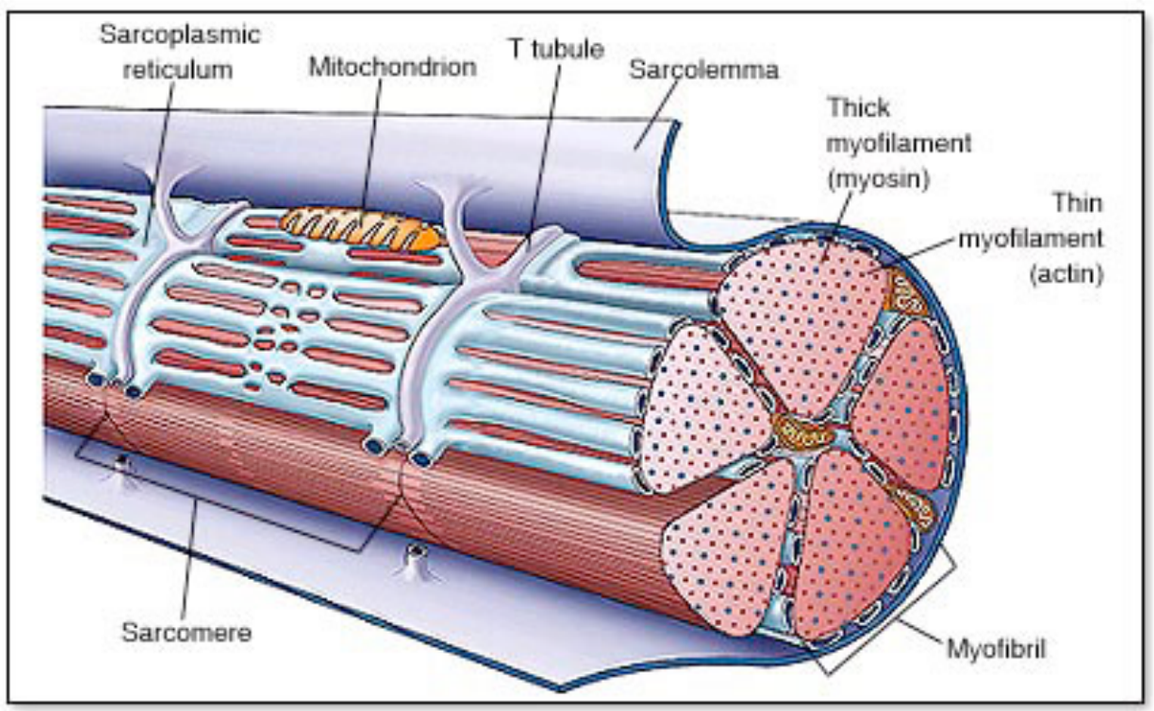
Muscular System

- Muscle cell function relies on microfilaments, the actin components of the cytoskeleton that function in cell motility.



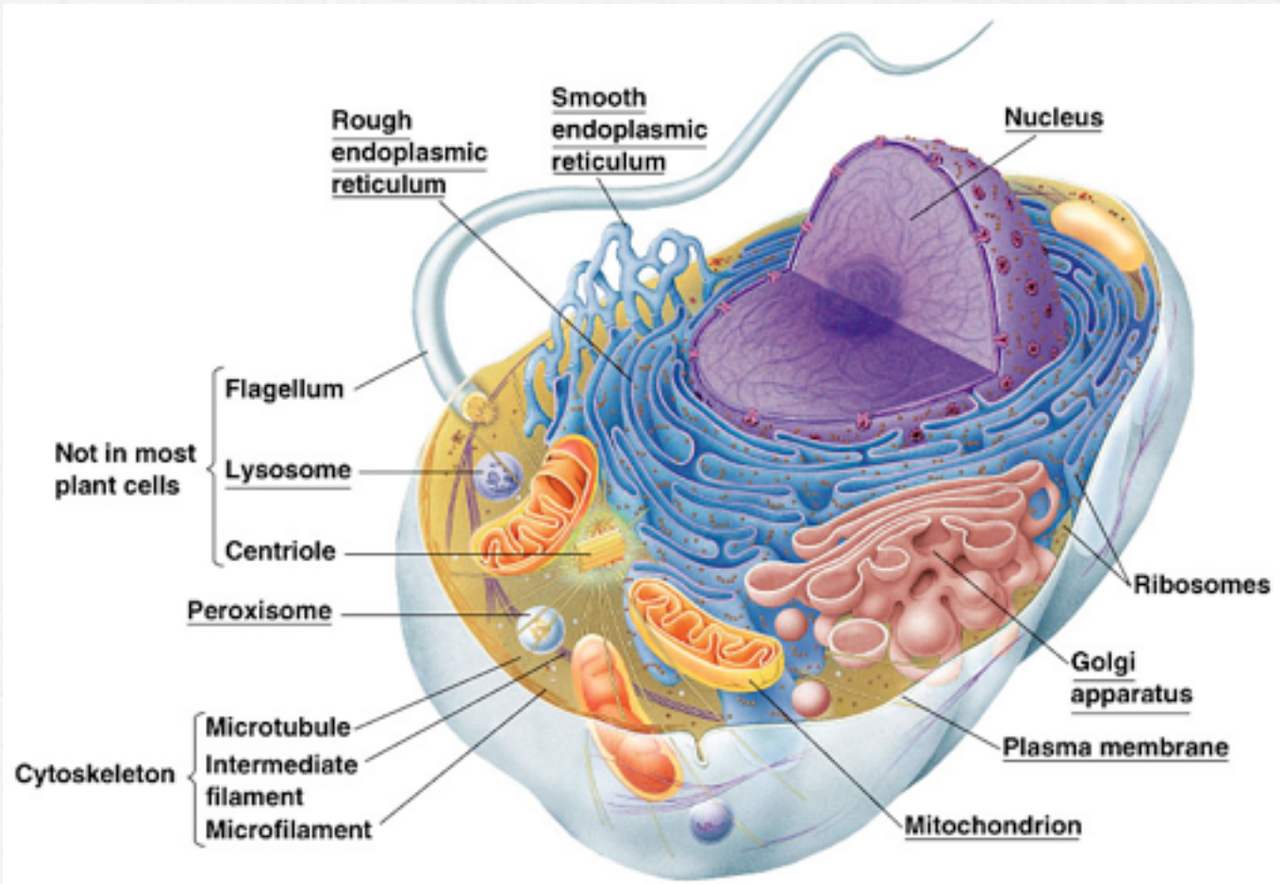
Muscle cells do not look like typical cells. "Typical cells" as depicted in textbooks have no function and their structure is used as starting point for teaching/learning.

Muscle cells do have a function and their structure reflects this function!

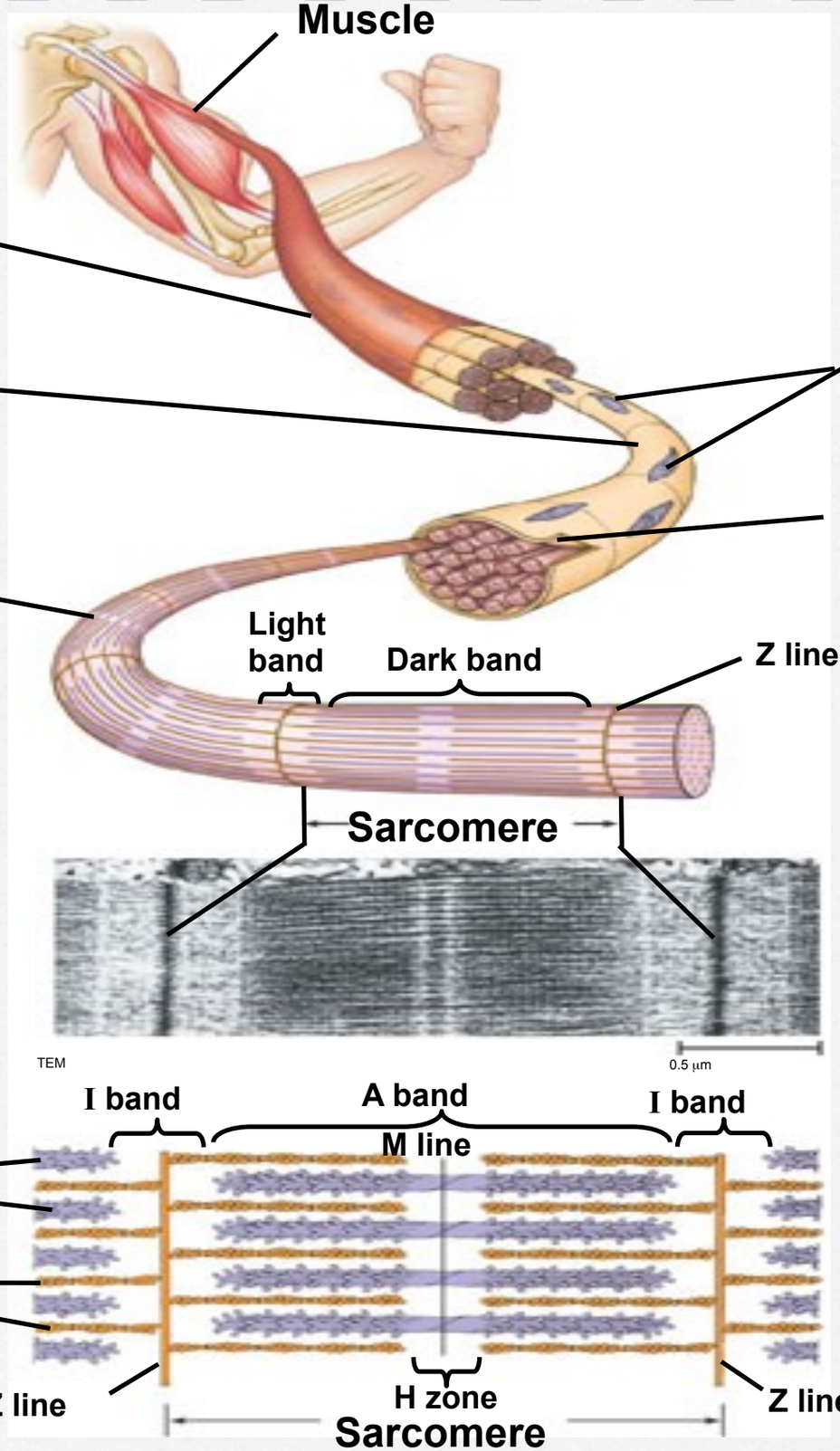


Muscle Cell

Typical Cell



Skeletal Muscle

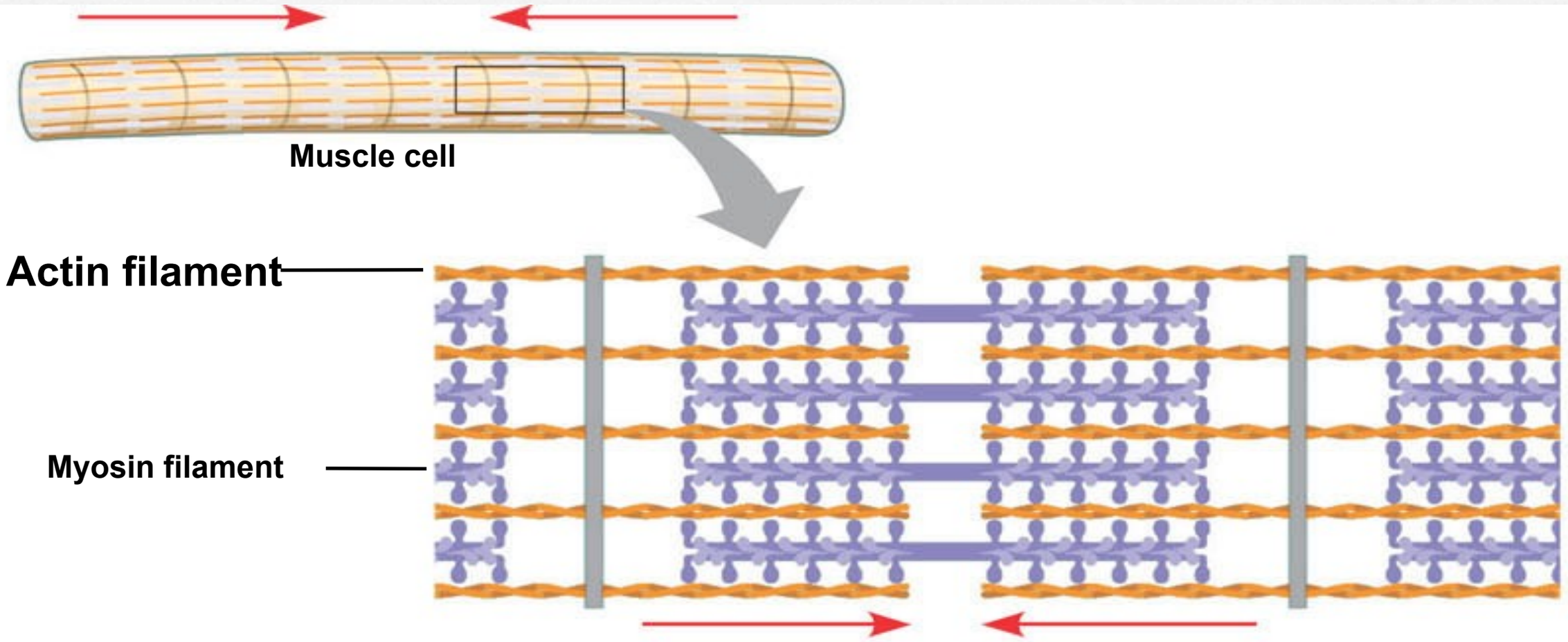


Multiple nuclei result from fusion of numerous embryonic cells

Basic contractile unit of muscle cells

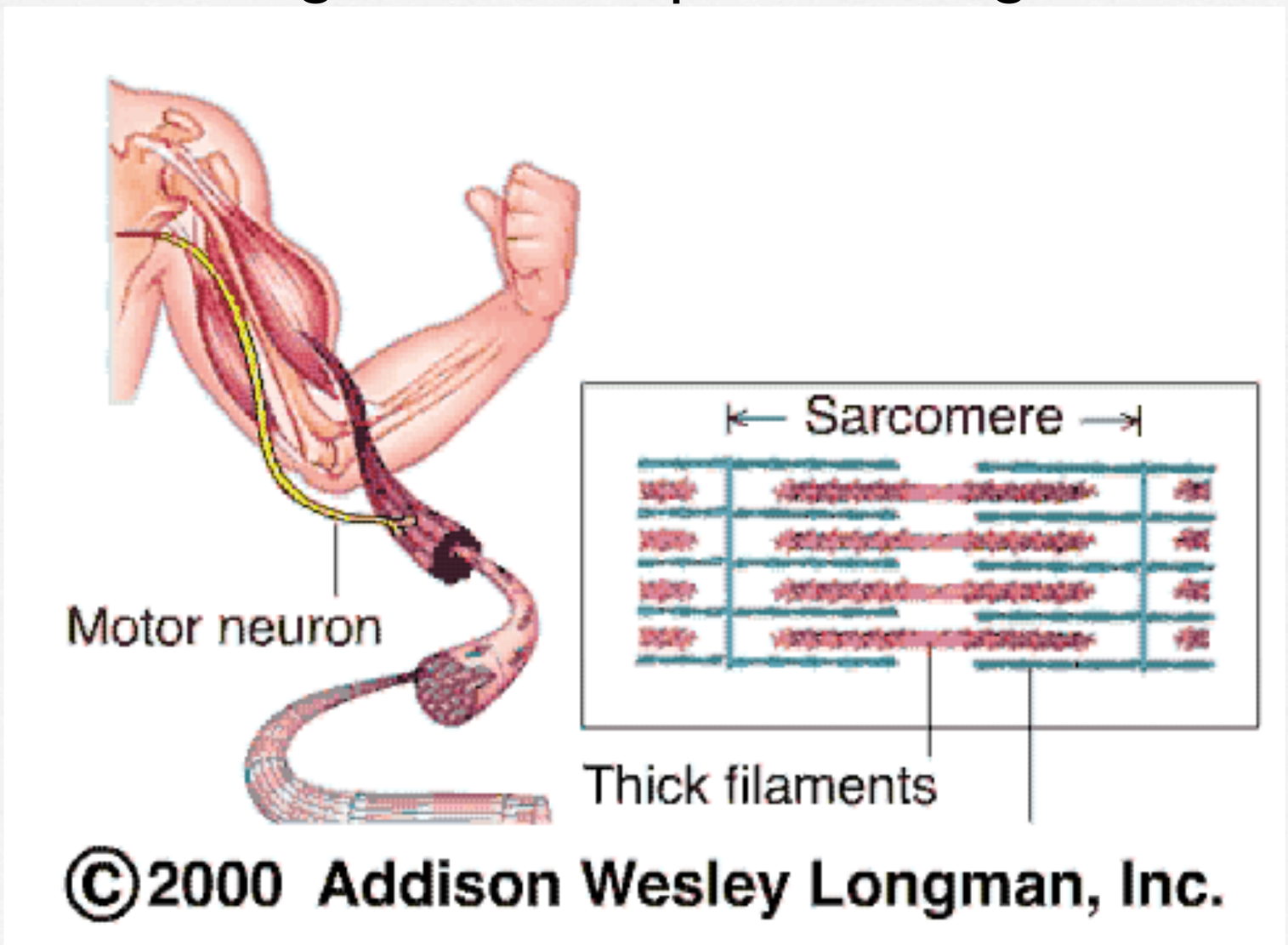
Sliding Filament Theory

- We can begin to understand muscle contraction by focusing on the contraction of a single sarcomere.



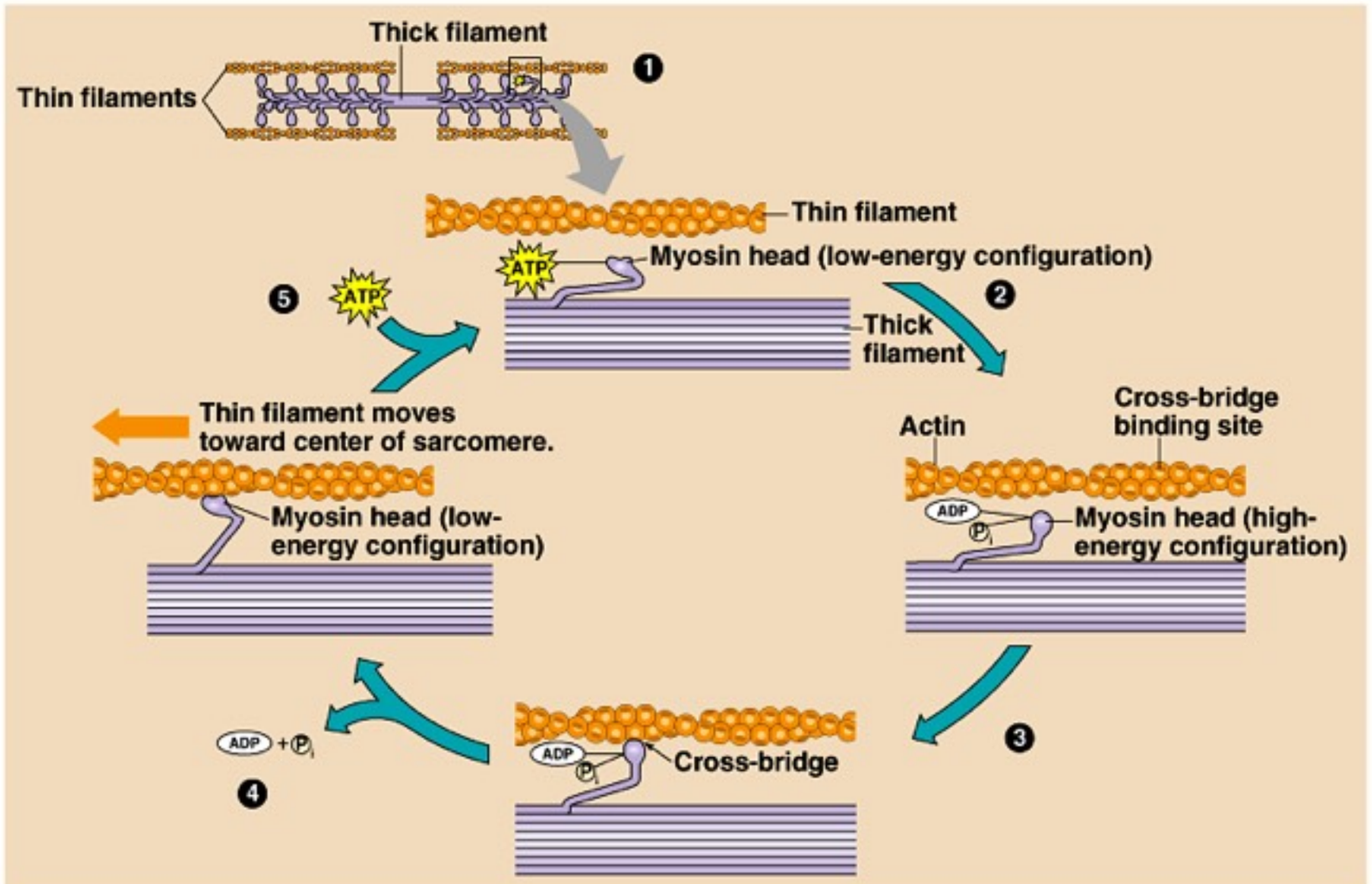
Sliding Filament Theory

- Sliding Filament Theory- the thin and thick filaments slide past one another, increasing their overlap, shortening the sarcomere.



Sliding Filament Theory

- Illustration Review



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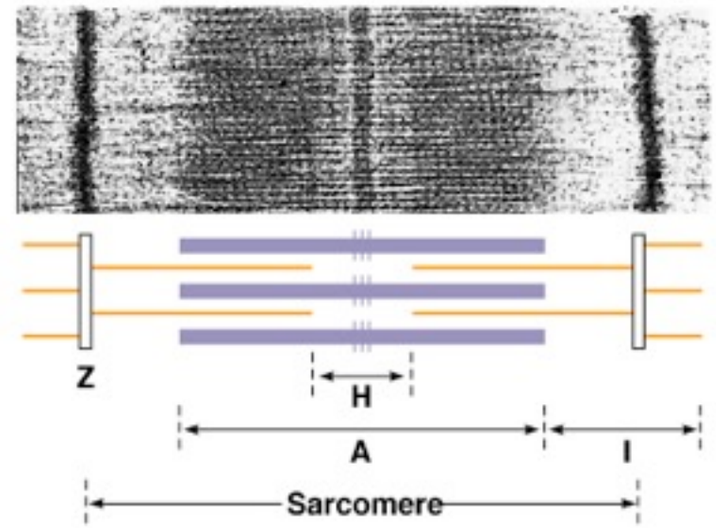
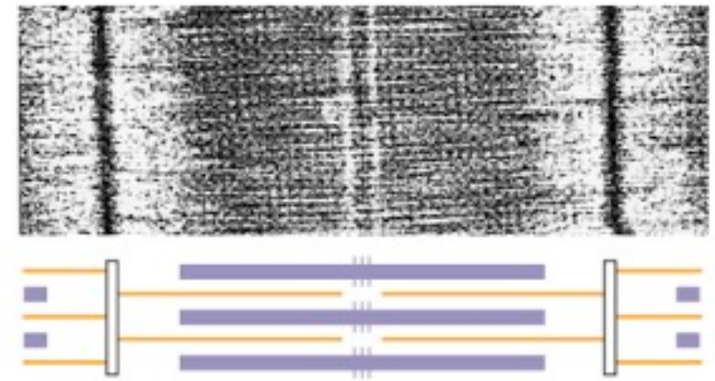
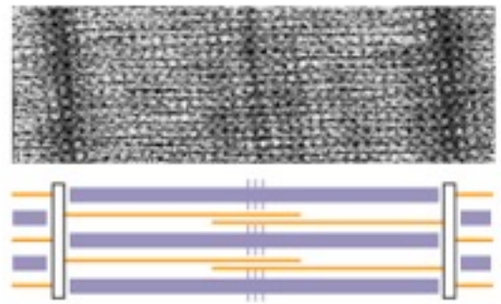


(a) Muscle relaxed (extended)



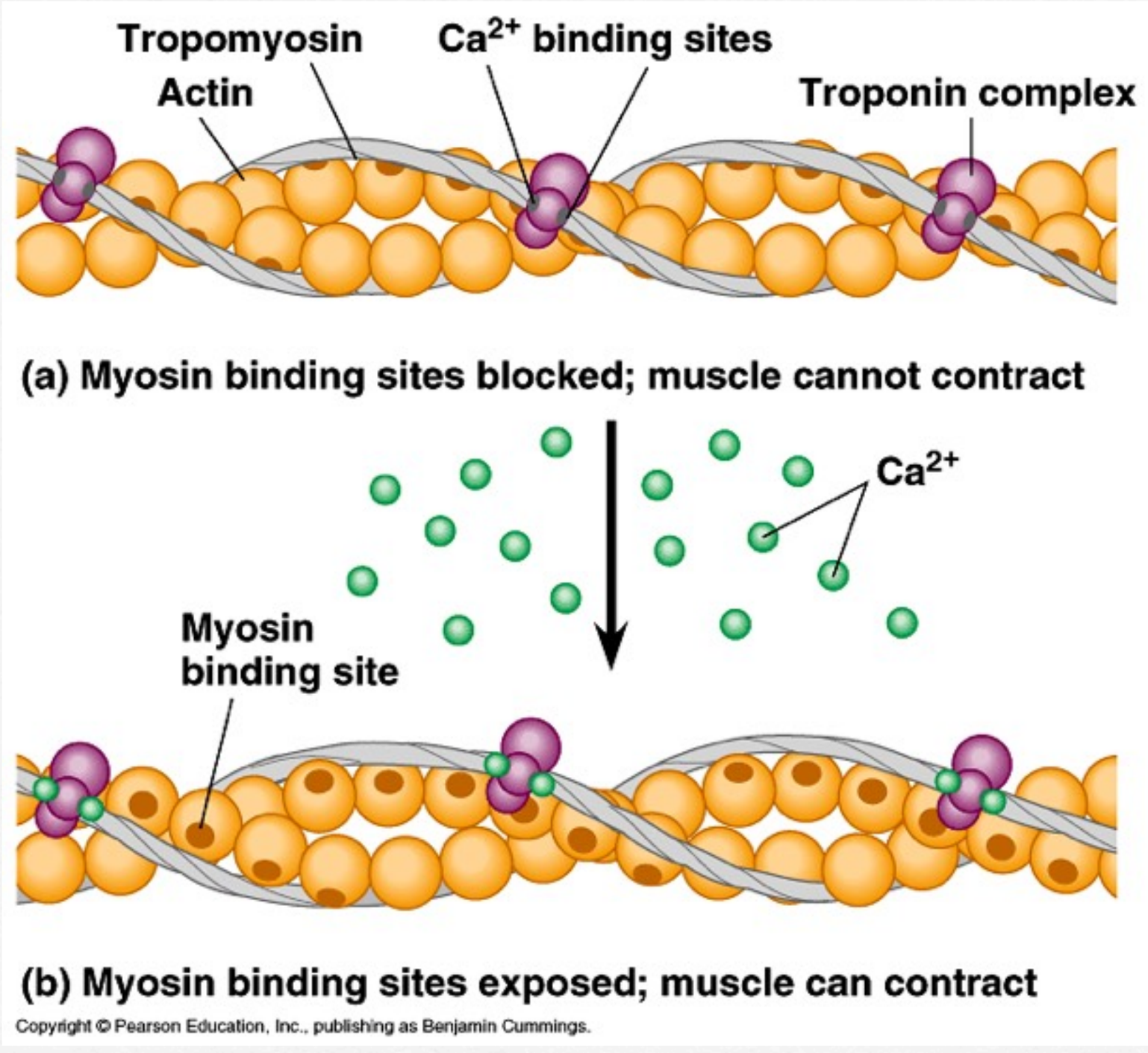
(b) Muscle contracting



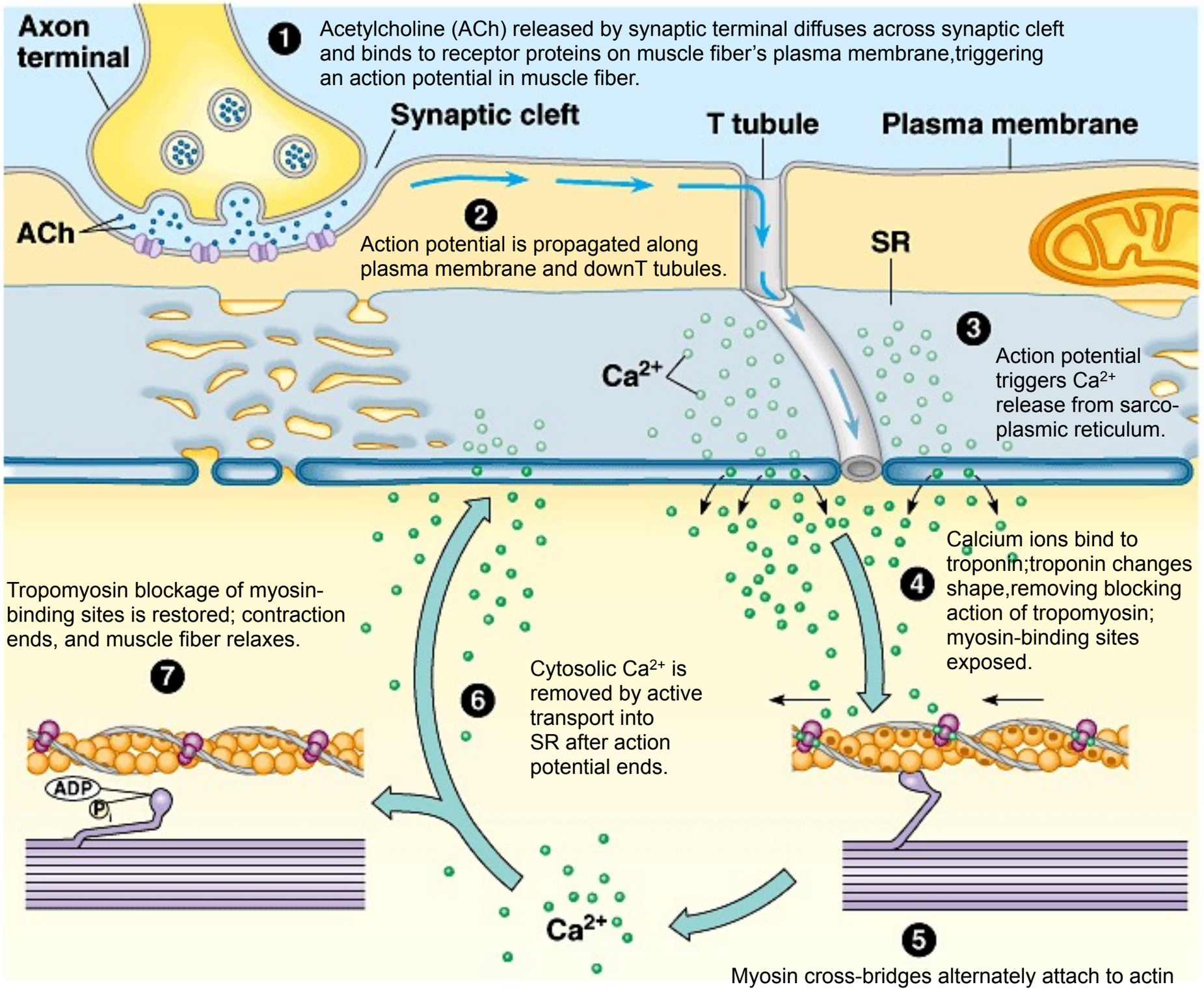
(c) Muscle contracted

Role of Calcium in Contraction

- Illustration Review



Skeletal Muscle Contraction Sequence



Plant Vascular Tissue & Leaf

- **See slides from 27-31**

Learning Objectives:

LO 4.8 The student is able to evaluate scientific questions concerning organisms that exhibit complex properties due to the interaction of their constituent parts. [See SP 3.3]

LO 4.9 The student is able to predict the effects of a change in a component(s) of a biological system on the functionality of an organism(s). [See SP 6.4]

LO 4.10 The student is able to refine representations and models to illustrate biocomplexity due to interactions of the constituent parts. [See SP 1.3]