Chapter 21.1

An Introduction to the Lymphatic and Immune Systems

What is the lymphatic system?

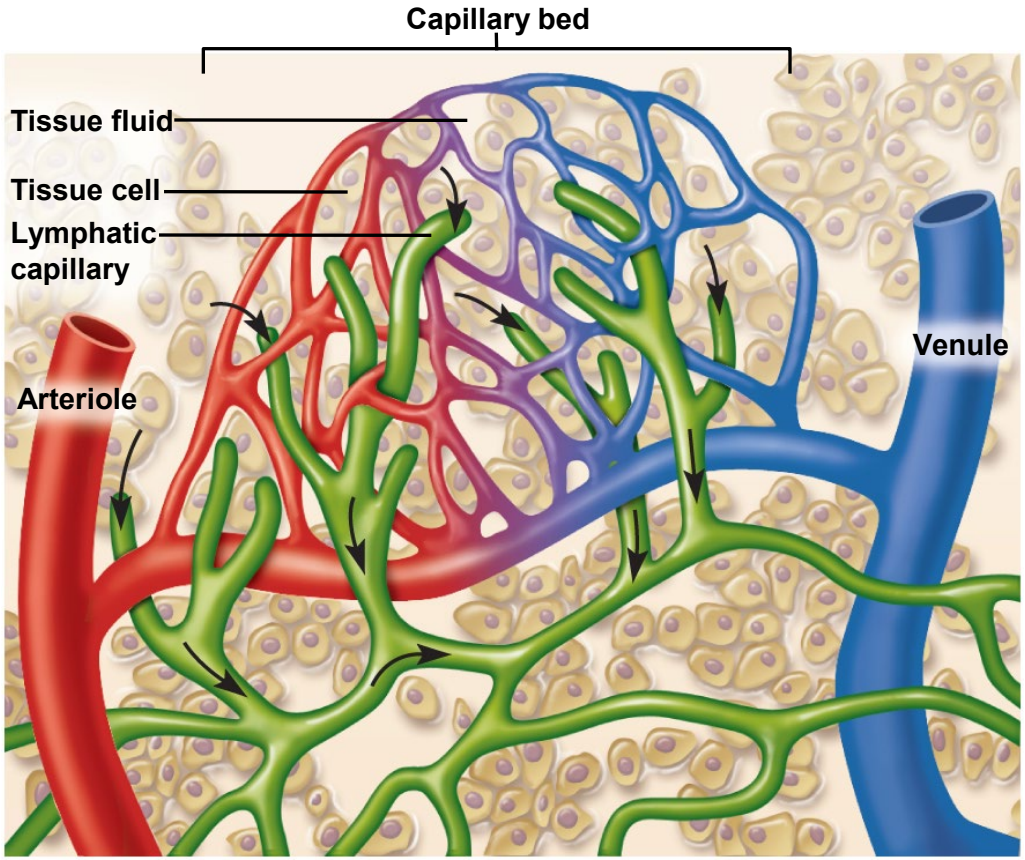
Lymphatic system provides three important functions in human physiology

Lymphatic system functions as a drainage system. Fluid leaks out from capillary beds into our tissue spaces and the lymphatic system returns this fluid to the systemic circuit (blood).

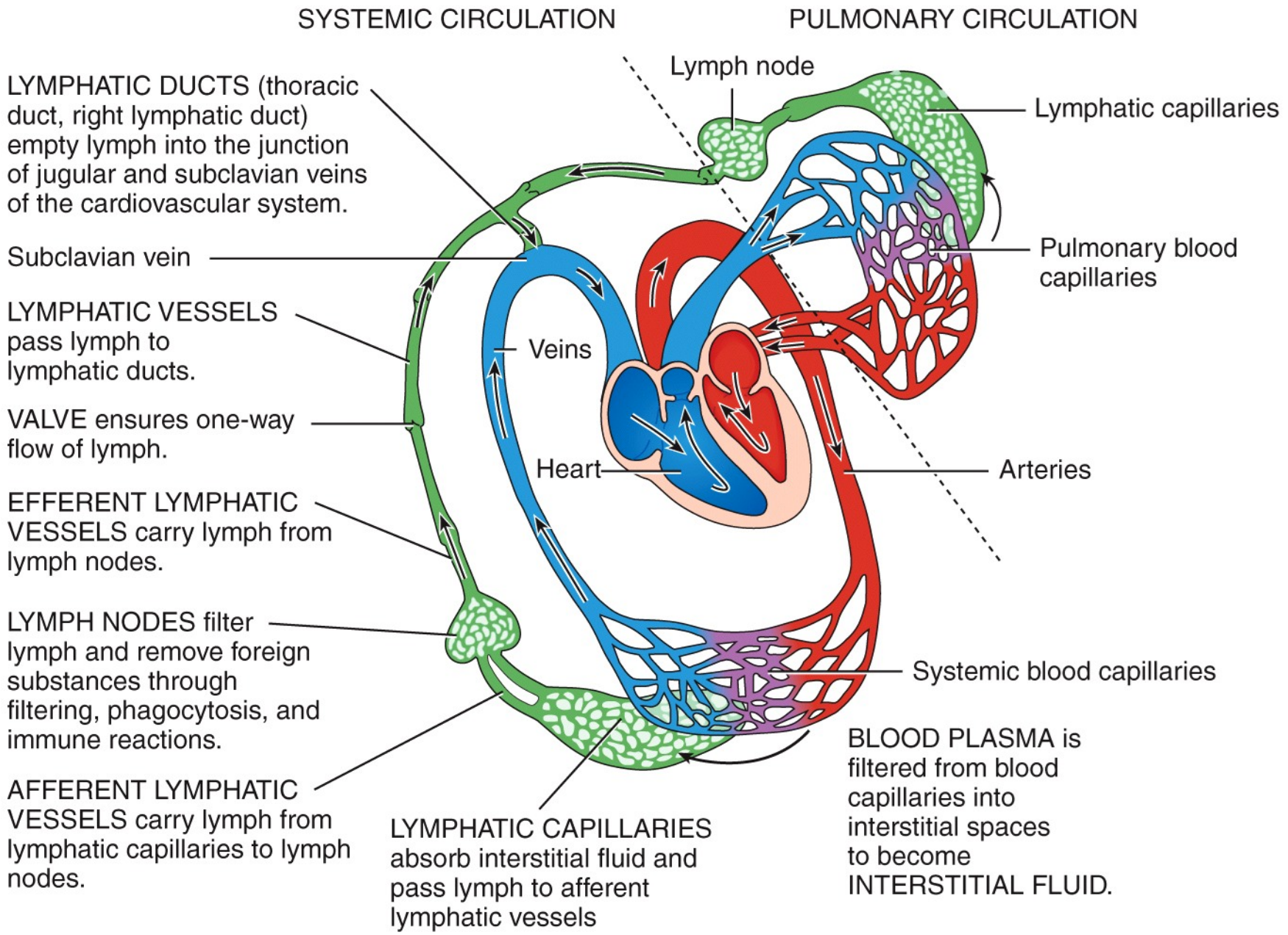
Lymphatic capillaries in the small intestine form lacteals used to transport fat in our diet into our body.

Lymphatic system functions as part of our immune system. Lymph (fluid that leaked out of blood capillaries) pass through lymph nodes (filters to remove cellular debris and pathogens) then returns to the systemic circuit. While in the lymph nodes, resting T cells and B cells recognize pathogens traveling in the lymph and initiate an immune response.

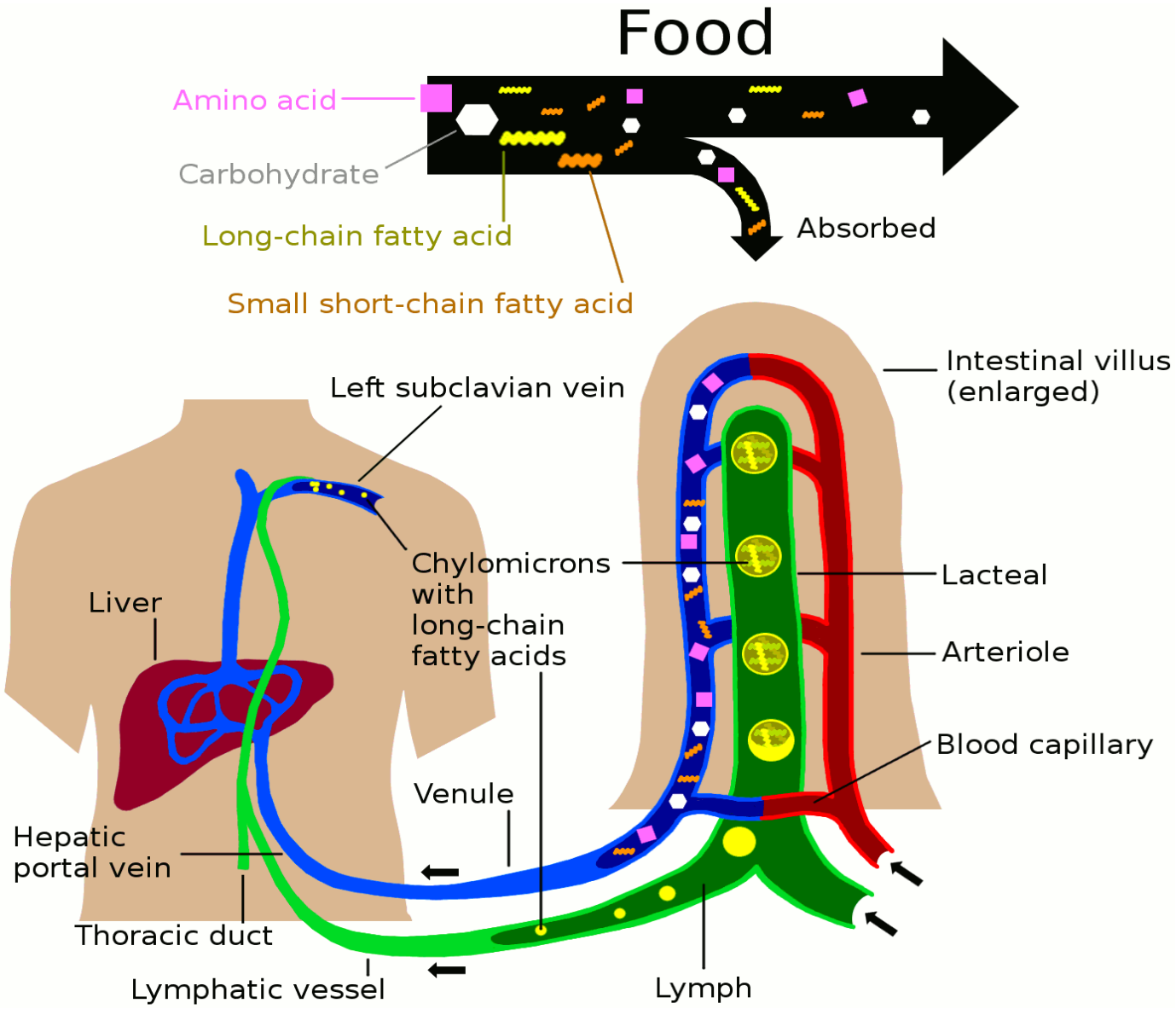
Structure of a Capillary Bed with Lymphatic Capillaries and Their Afferent Vessels



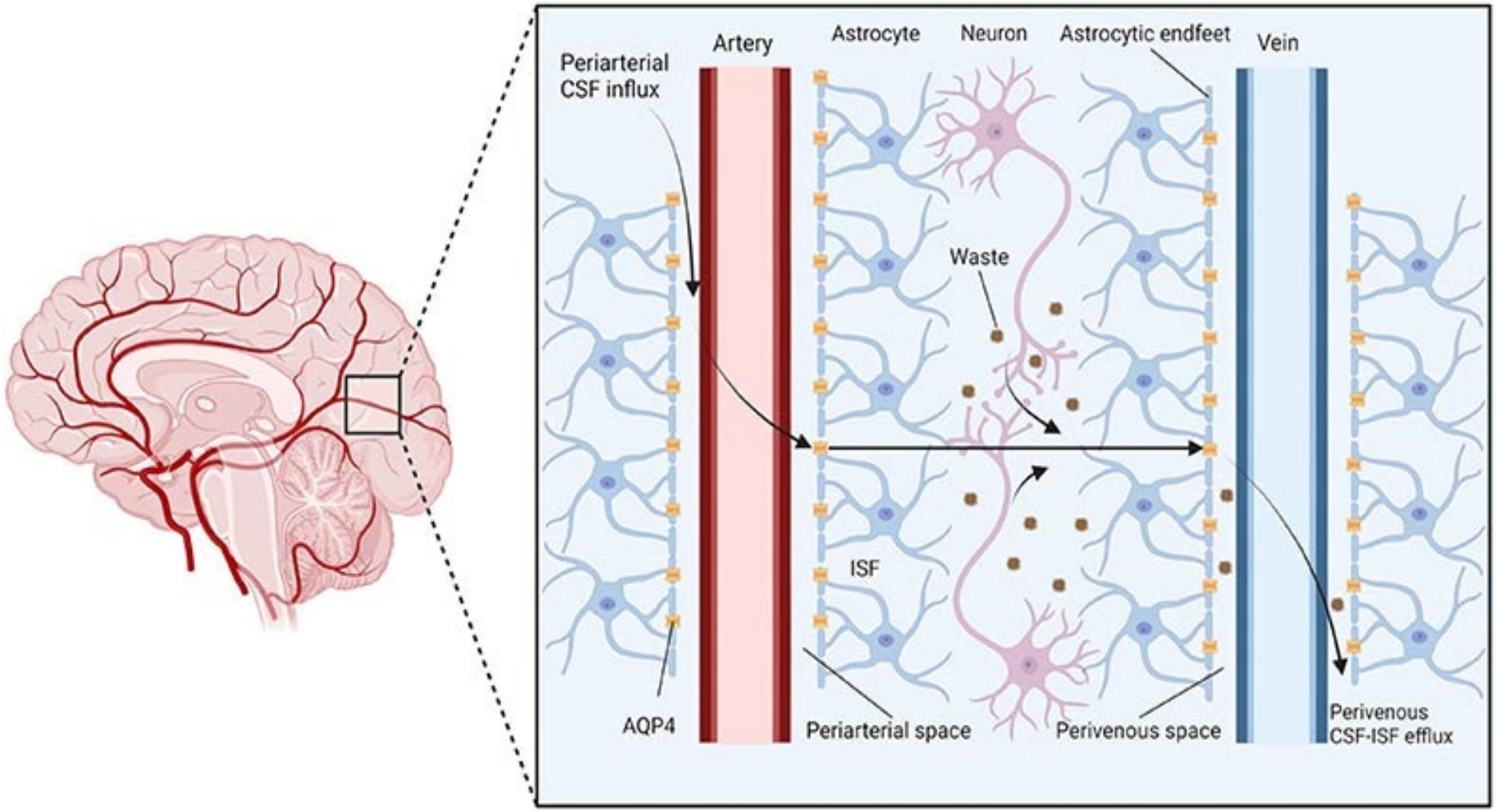
How much fluid is not recovered at the end of the capillary bed? (15%)


SYSTEMIC CIRCULATION
PULMONARY CIRCULATION
Lymph node
Lymphatic capillaries
LYMPHATIC DUCTS (thoracic duct, right lymphatic duct) empty lymph into the junction of jugular and subclavian veins of the cardiovascular system.
Subclavian vein
Pulmonary blood capillaries
LYMPHATIC VESSELS pass lymph to lymphatic ducts.
Veins
VALVE ensures one-way flow of lymph.
Heart
Arteries
EFFERENT LYMPHATIC VESSELS carry lymph from lymph nodes.
LYMPH NODES filter lymph and remove foreign substances through filtering, phagocytosis, and immune reactions.
Systemic blood capillaries
BLOOD PLASMA is filtered from blood capillaries into interstitial spaces to become INTERSTITIAL FLUID.
AFFERENT LYMPHATIC VESSELS carry lymph from lymphatic capillaries to lymph nodes.
LYMPHATIC CAPILLARIES absorb interstitial fluid and pass lymph to afferent lymphatic vessels

Lacteal Role in Fat Absorption



New Function for Astrocytes in the CNS



Glymphatic System

The glymphatic system is a network of fluid-filled channels in the brain that plays a crucial role in clearing waste products and toxins from the central nervous system.

Function:

Waste removal:

The glymphatic system transports cerebrospinal fluid (CSF) through the brain, carrying waste products, such as proteins, toxins, and dead cells, away from the brain tissue.

Metabolic regulation:

It helps maintain the chemical balance of the brain by removing metabolic waste products.

Immune function:

The glymphatic system facilitates the movement of immune cells into the brain, aiding in immune surveillance.

Structure:

The glymphatic system consists of:

- **Perivascular spaces:** These are narrow channels that surround blood vessels in the brain.
- **Interstitial fluid:** Fluid that fills the spaces between cells in the brain.
- **Aquaporin-4 (AQP4):** These proteins, located on the cells lining the perivascular spaces, allow CSF to flow into the brain tissue.

Activation:

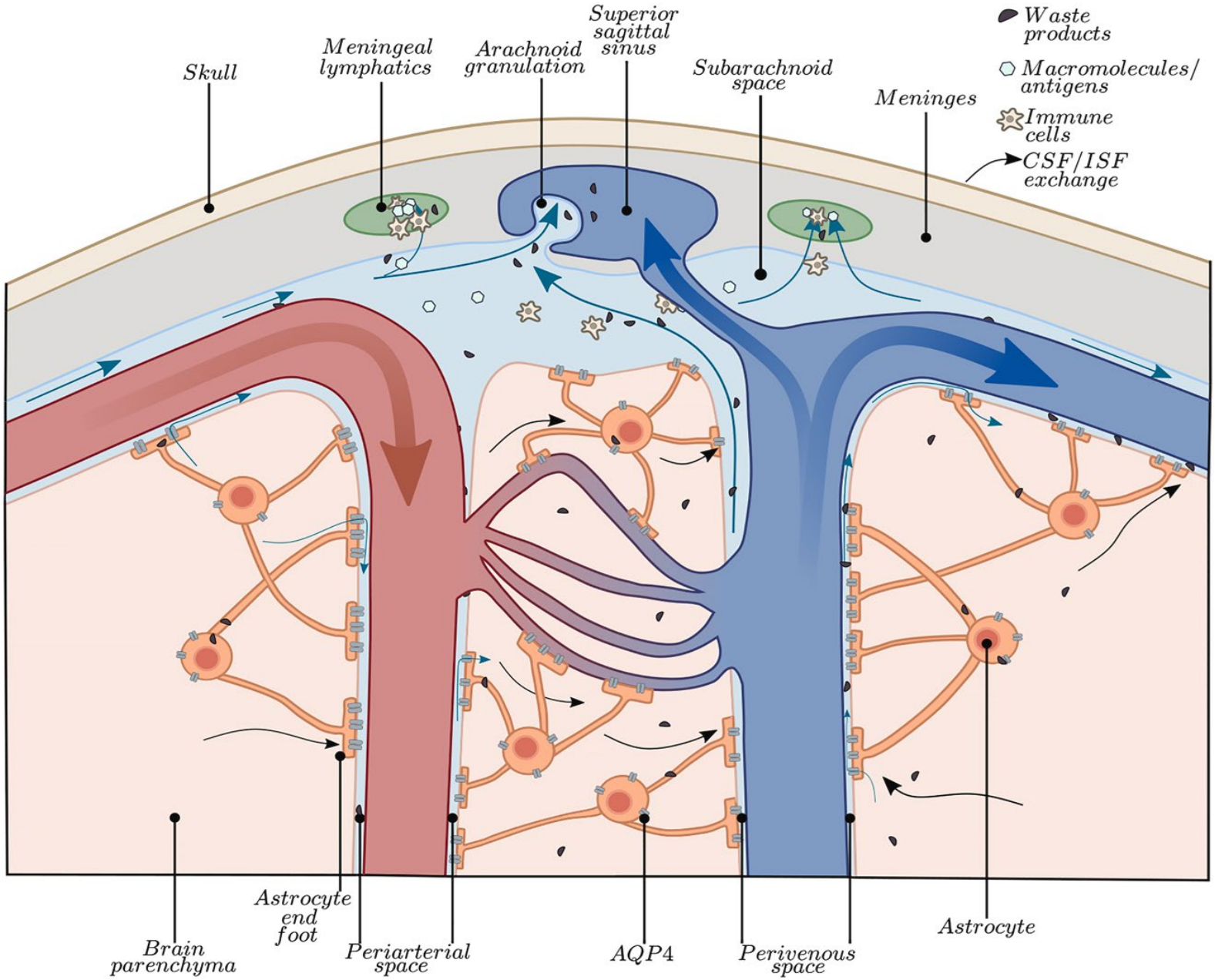
The glymphatic system is most active during sleep. During sleep, CSF pressure increases, driving fluid into the brain tissue and facilitating waste removal. Exercise and certain medications can also enhance glymphatic activity.

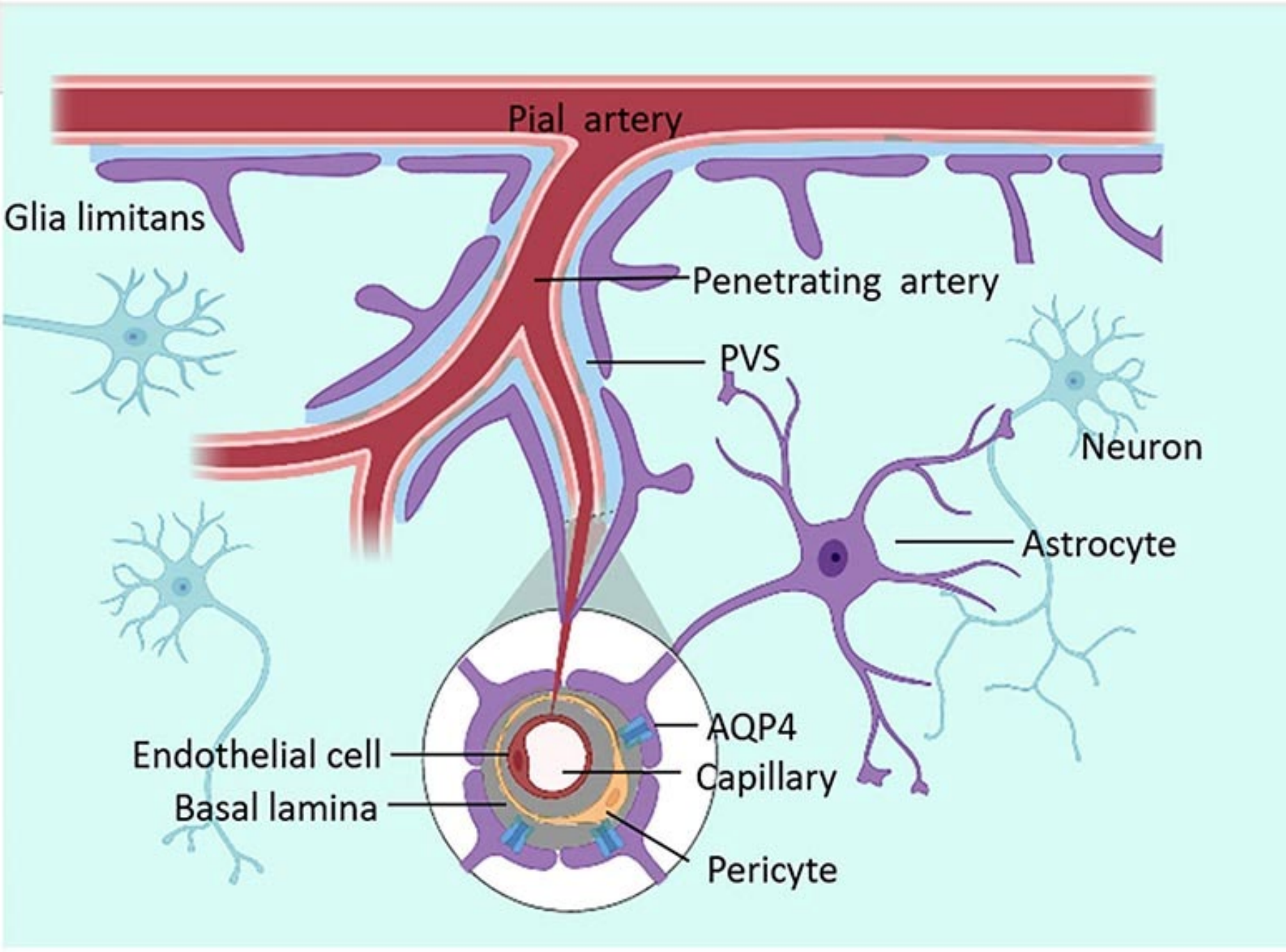
Importance:

The glymphatic system is essential for maintaining brain health. Dysregulation of the glymphatic system has been implicated in various neurological disorders, including Alzheimer's disease, multiple sclerosis, and traumatic brain injury.

Additional Notes:

- The glymphatic system was discovered in 2012.
- Research on the glymphatic system is ongoing, and there is still much to learn about its function and potential therapeutic applications.
- It is important to note that the glymphatic system is distinct from the lymphatic system, which is responsible for draining fluid from other parts of the body.


Skull
Meningeal lymphatics
Arachnoid granulation
Superior sagittal sinus
Subarachnoid space
Meninges
Waste products
Macromolecules/ antigens
Immune cells
CSF/ISF exchange
Brain parenchyma
Astrocyte end foot
Periarterial space
AQP4
Perivenous space
Astrocyte


Pial artery
Glia limitans
Penetrating artery
PVS
Neuron
Astrocyte
AQP4
Endothelial cell
Capillary
Basal lamina
Pericyte

What is the immune system?

The immune system is not an “organ system”.

The immune system is a collection of cells without adhesion molecules.

The immune system's cells are “nomadic”, free to move between the blood, interstitial spaces, and follow connective tissue into the organs of the body.

The immune system's cells seek to identify and destroy pathogens.

Pathogens cause diseases in a healthy person.

What is the relationship between the lymphatic system and the immune system?

Lymph nodes plays key role in protecting our body from pathogens (e.g. bacteria). Lymph nodes are resting sites for many immune cells (T cells, B cells, macrophage)

As lymph moves through a lymph node – the fluid is inspected for signs of pathogen by Antigen Processing Cells (B cells, dendritic cells, macrophage).

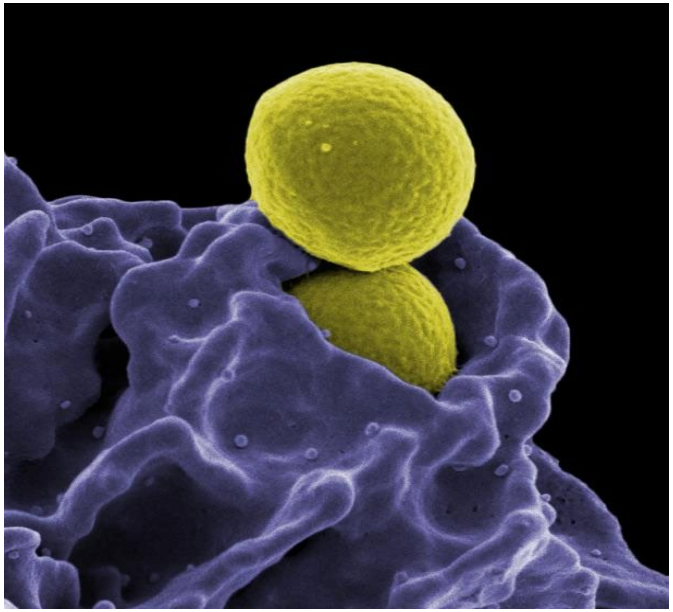
APC ingest and process pathogen's antigen, placing the antigen on the outer surface of the APC plasma membrane.

Now the APC may "activate" the cytotoxic-T-cells (cTc), helper T-cells (hTc), and B cells.

APC are required to activate helper T cells, cytotoxic T cells, and B cells

B cells = humoral immunity

T cells = cellular immunity



MERSA being engulf by WBC

We have ten bacteria (prokaryotic cell structure) for each human cell (eukaryotic cell structure).

Therefore, 90% of the cells that make-up the human body are foreign prokaryotic cells

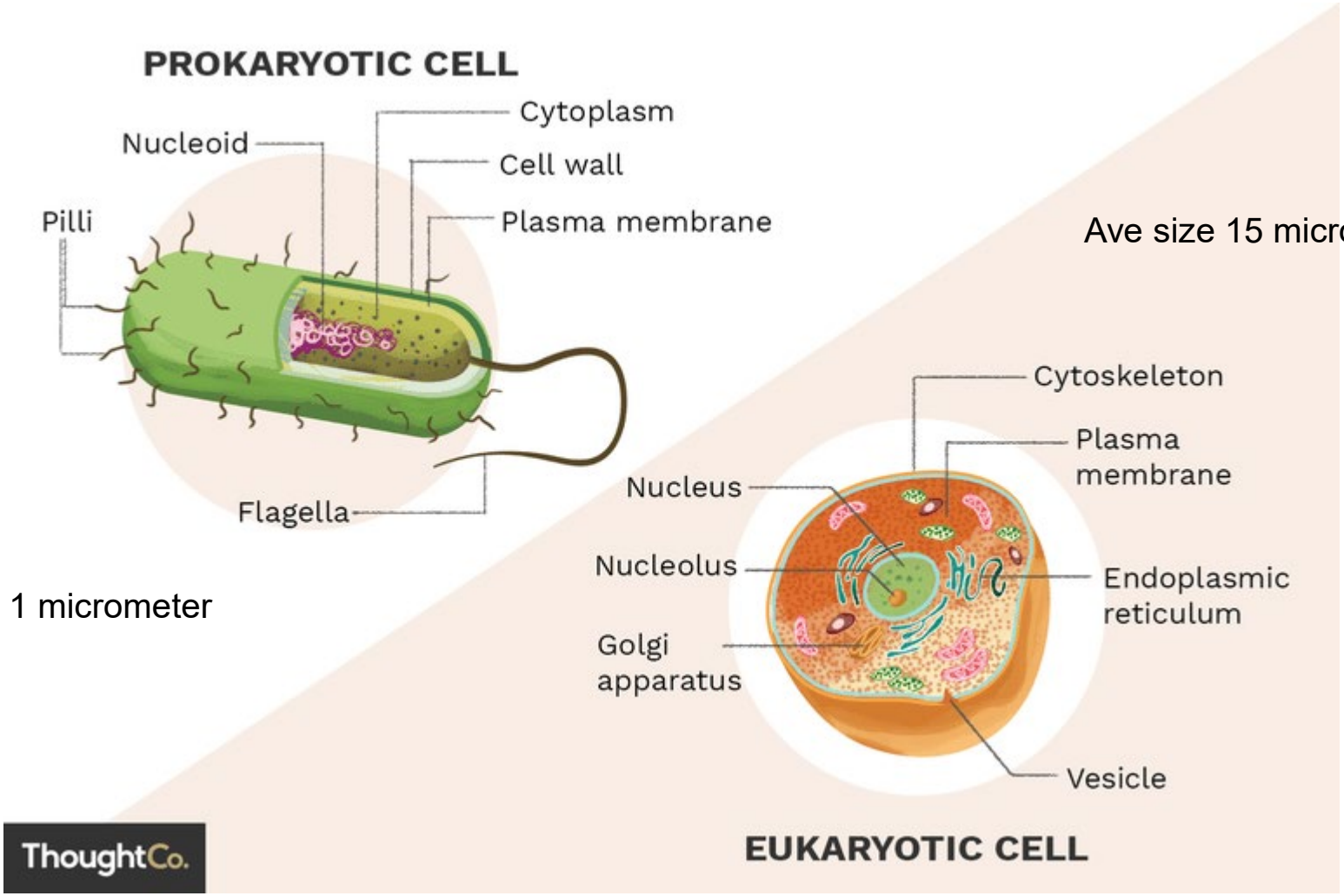
Prokaryotic cells are very small (one micrometer) vs eukaryotic cells (10 micrometer)

All these prokaryotic cells together weigh less than 2-lbs. It's like an extra average size human organ!

Some of these bacteria are beneficial /// e.g. some bacteria form an invisible “shield” over our skin and mucous membranes to protect us!

Other bacteria are pathogens and able to cause diseases – these must be eliminated

How do we defend ourselves against these threats?



- Prokaryotic cell has single circular chromosome
- Eukaryotic cell has many lineal chromosome (humans 46).

The Immune System Has Three Separate Lines of Defenses

1) Physical barriers (innate immunity)

2) Nonspecific resistance (innate immunity) = Anti microbial proteins // Phagocytes // Surveillance cells (i.e. NK cells) // Complement // Inflammation (a multi-step process)

3) Acquired Immunity also call Adaptive Immunity (not innate)

> population of WBC that wander and inhabit all of our organs
> defend the body from agents of disease (pathogens)
> especially concentrated in the lymphatic system
> these cells must be born, educated, and deployed
> after being deployed, these cells can recognize / react (attack) / remember
> there are billions of possible antigens
> adaptive immunity must produce a set of three cells with identical receptors
> one for cellular immunity, one for humoral immunity, and one for the “helper”
> key features of immune system = **specificity and memory**