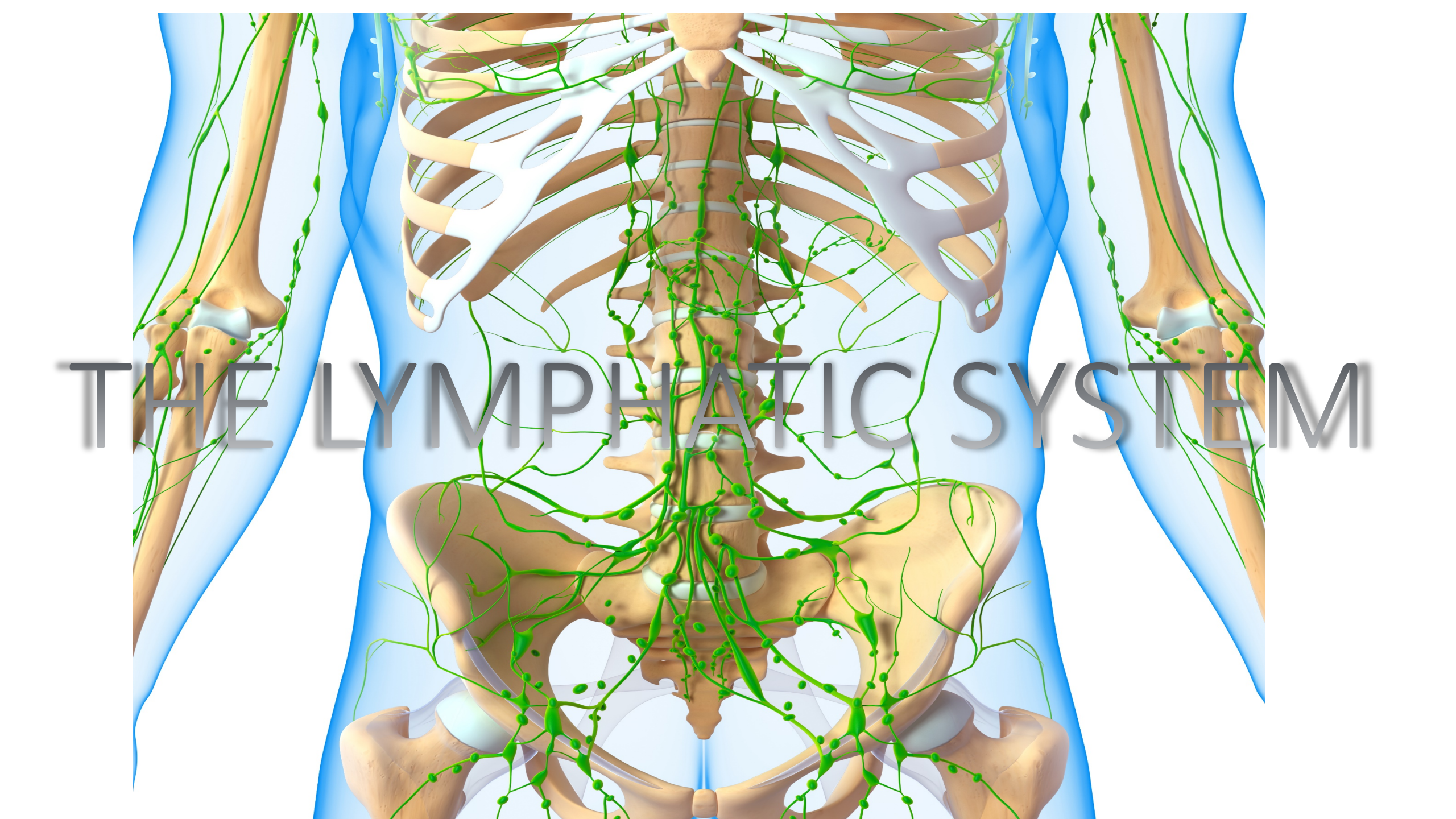


# Lecture Exam 5 Study Guide

- TOPICS: The Lymphatic System and The Digestive System

An anatomical illustration of the human lymphatic system. The image shows a human torso from the neck to the pelvis, with the skeletal structure (ribs, spine, and pelvic/shoulder girdles) rendered in a realistic tan color. Overlaid on this is a network of green lymphatic vessels and nodes. The vessels are thin and thread-like, branching out from the central spine and extending to the arms and legs. Nodes are represented as small, rounded green spheres along these vessels. The background is a light blue, semi-transparent skin layer. The text "THE LYMPHATIC SYSTEM" is centered across the middle of the image in a large, grey, sans-serif font.

# THE LYMPHATIC SYSTEM

# OBJECTIVES



Describe the structure and function of the lymphatic tissue (lymph fluid, vessels, ducts, and organs)



Describe the structure and function of the primary and secondary lymphatic organs



Discuss the cells of the immune system, how they function, and their relationship with the lymphatic system

## LYMPHATIC SYSTEM

The tonsils, adenoids, spleen and thymus are all part of the lymphatic system.

**Tonsils:** .....  
A large cluster of lymphatic cells found in the pharynx.

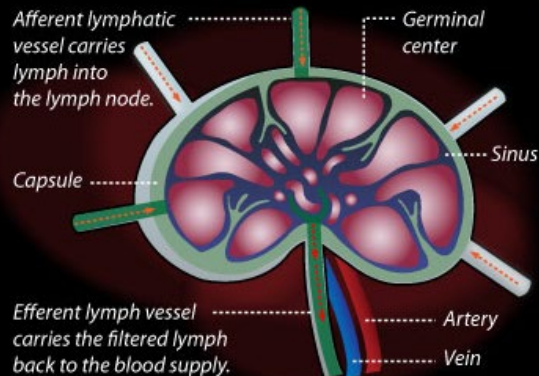
**Thymus:** .....  
This organ is where T-cells mature. T-cells help destroy infected or cancerous cells.

**Lymph nodes:** .....  
Produce and store cells that fight infection and disease. There are 600 to 700 lymph nodes in the human body.

**Spleen:** .....  
The largest lymphatic organ in the body contains white blood cells that fight infection or disease.

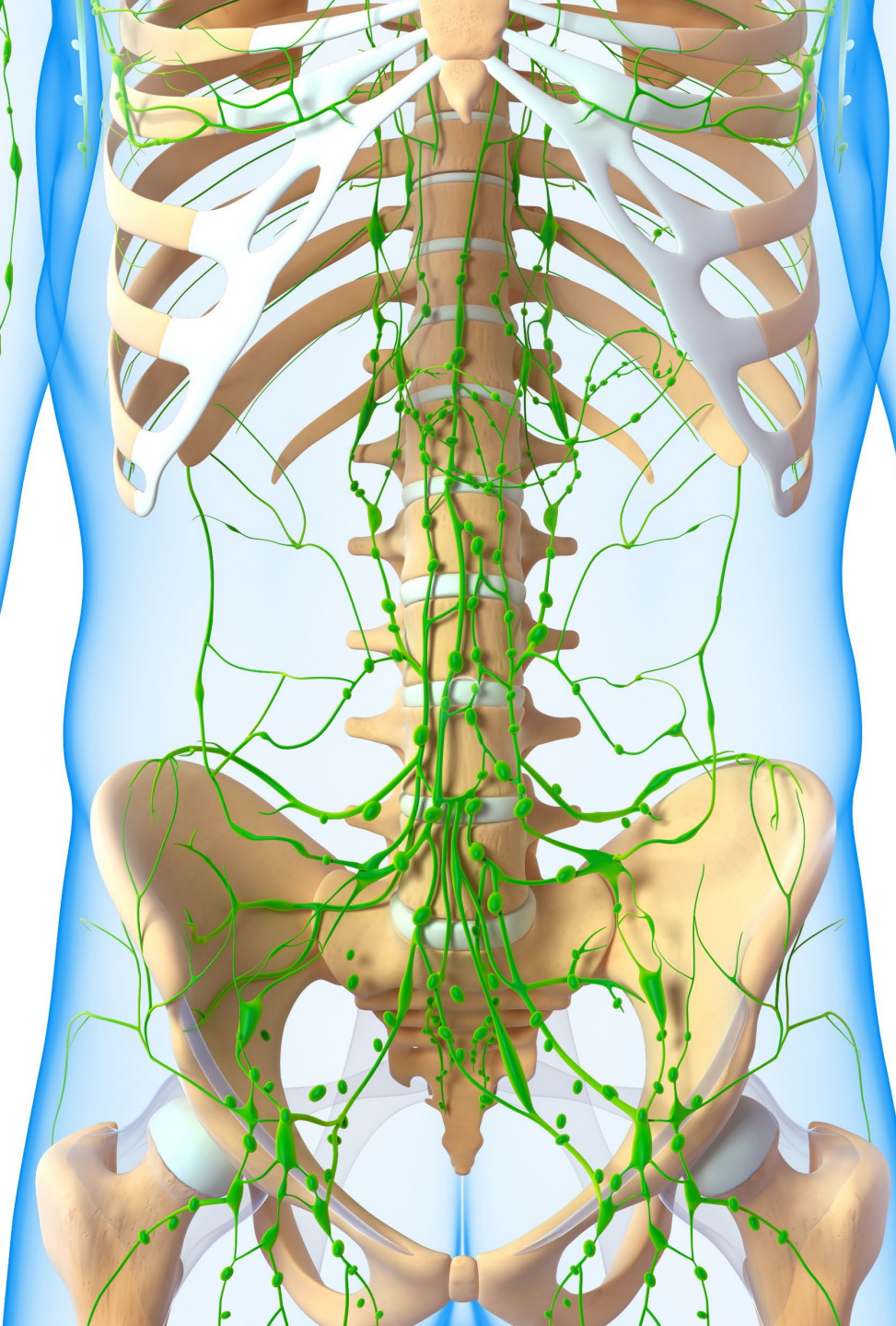
## LYMPH NODES

These small oval structures are an important component of the body's immune system and help in fighting infections. They function as filters of lymph, catching any debris or cells present in the lymph.



# What is the Lymphatic System?

- **The lymphatic system** is a series of **vessels**, ducts, and trunks that remove interstitial fluid from the tissues and return it the blood.

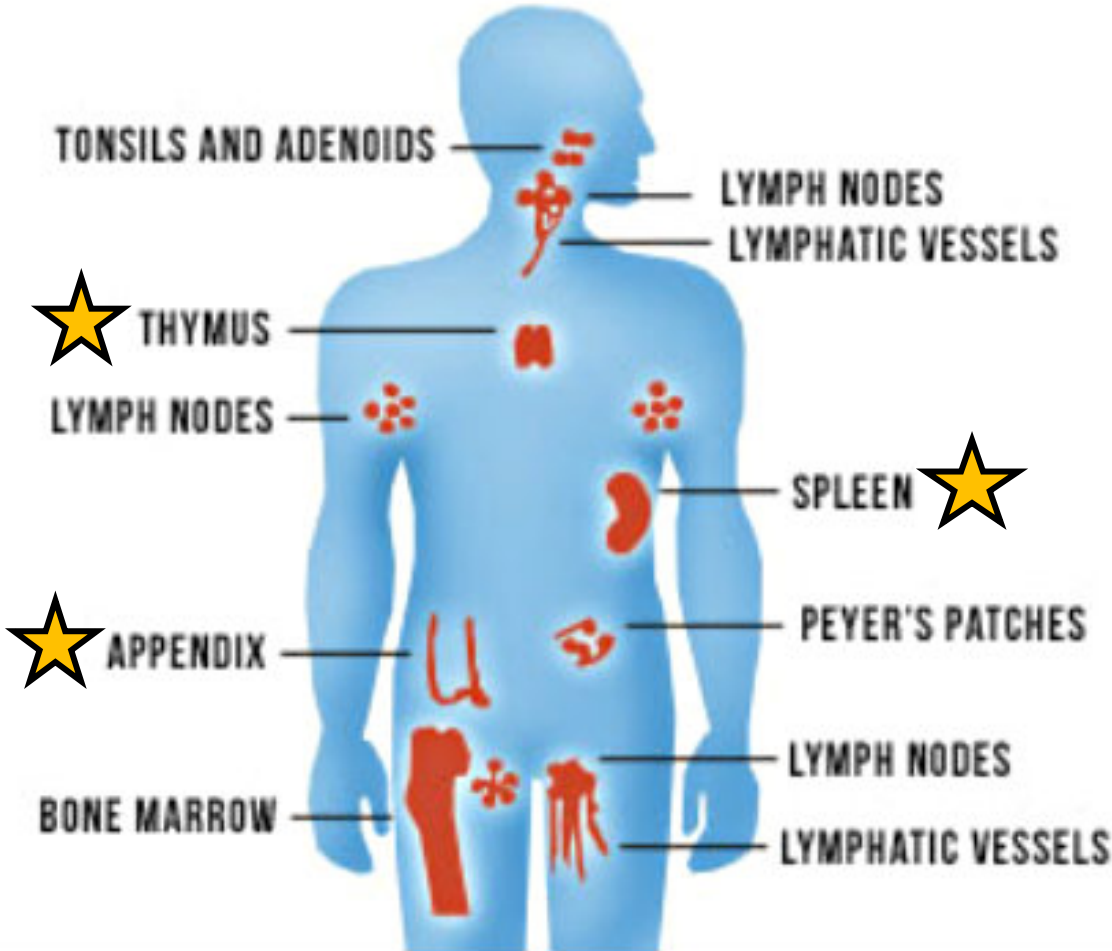


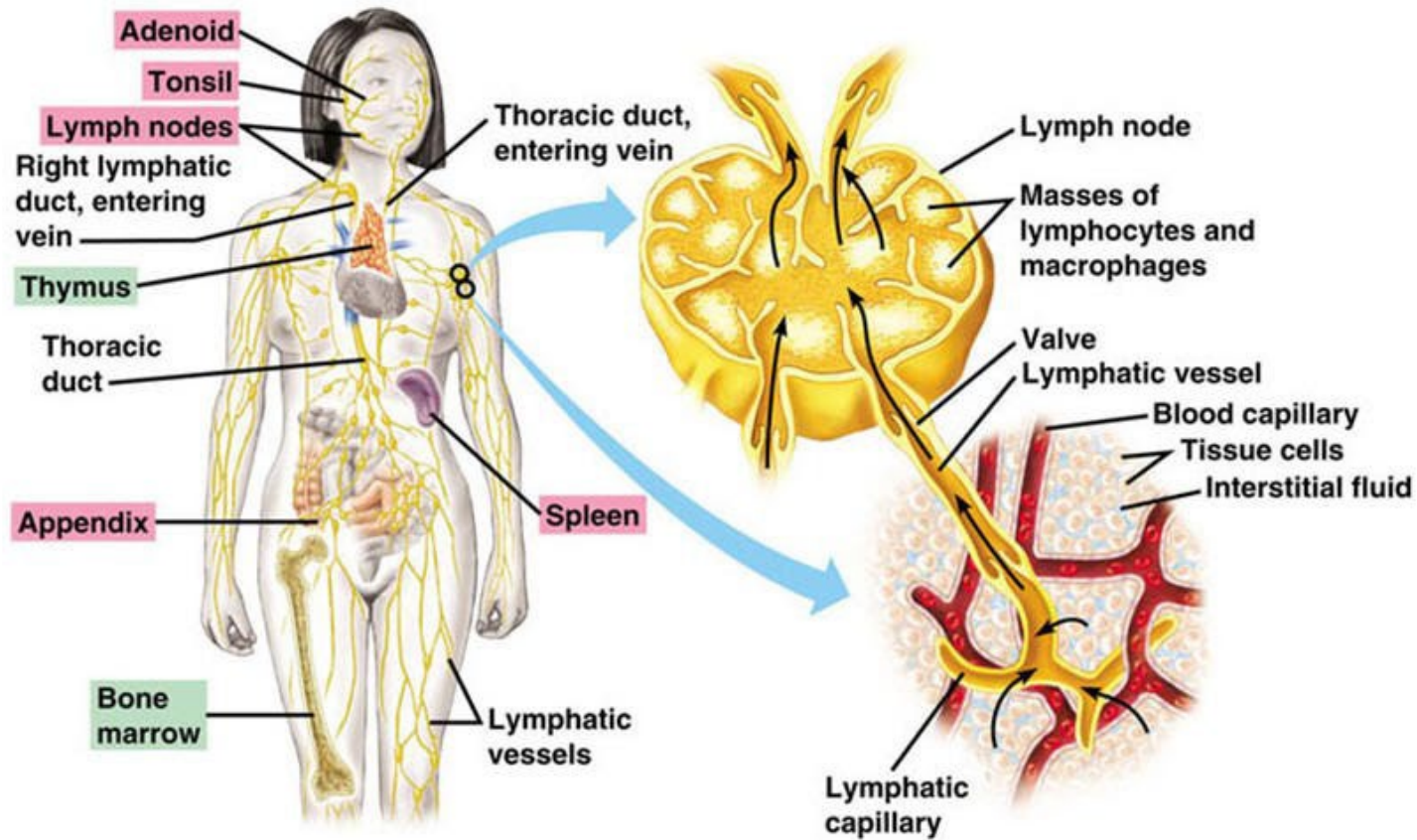
# Functions of the lymphatic system

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- Carries excess fluids to the bloodstream
- Filters pathogens from the blood
- Lymph nodes swell during an infection
- Transports immune cells (white blood cells or lymphocytes)

# ORGANS OF THE IMMUNE SYSTEM





- A major function of the lymphatic system is to **drain body fluids** and **return them to the bloodstream**.
  - Blood pressure causes leakage of fluid from the capillaries, resulting in the accumulation of fluid in the interstitial space.
  - Once this filtrate is out of the bloodstream and in the tissue spaces, it is referred to as interstitial fluid.

## Lymphatic System – Fluid Transport

# Functions of the Lymphatic System



~20 liters of fluid (plasma) diffuses out of the blood vessels at the level of the capillaries



~17 liters of this interstitial fluid is reabsorbed directly by the blood vessels.



~3 liters is brought back to the blood vessels through lymphatic vessels - via a series of vessels, trunks, and ducts.

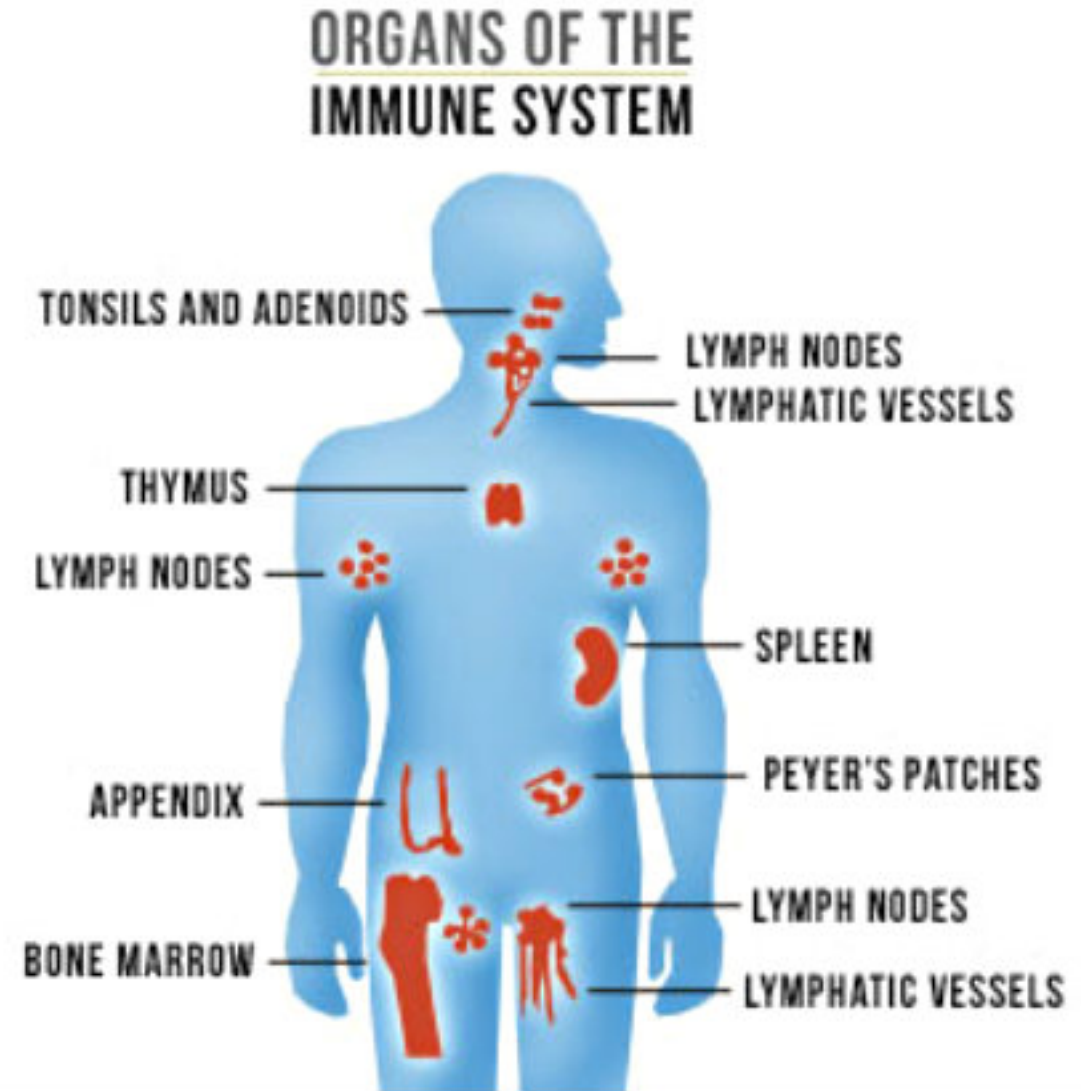


# TABLE 1. LYMPHOCYTES

Type of lymphocyte	Primary function
B lymphocyte	Generates diverse antibodies
T lymphocyte	Secretes chemical messengers
Plasma cell	Secretes antibodies
NK cell	Destroys virally infected cells

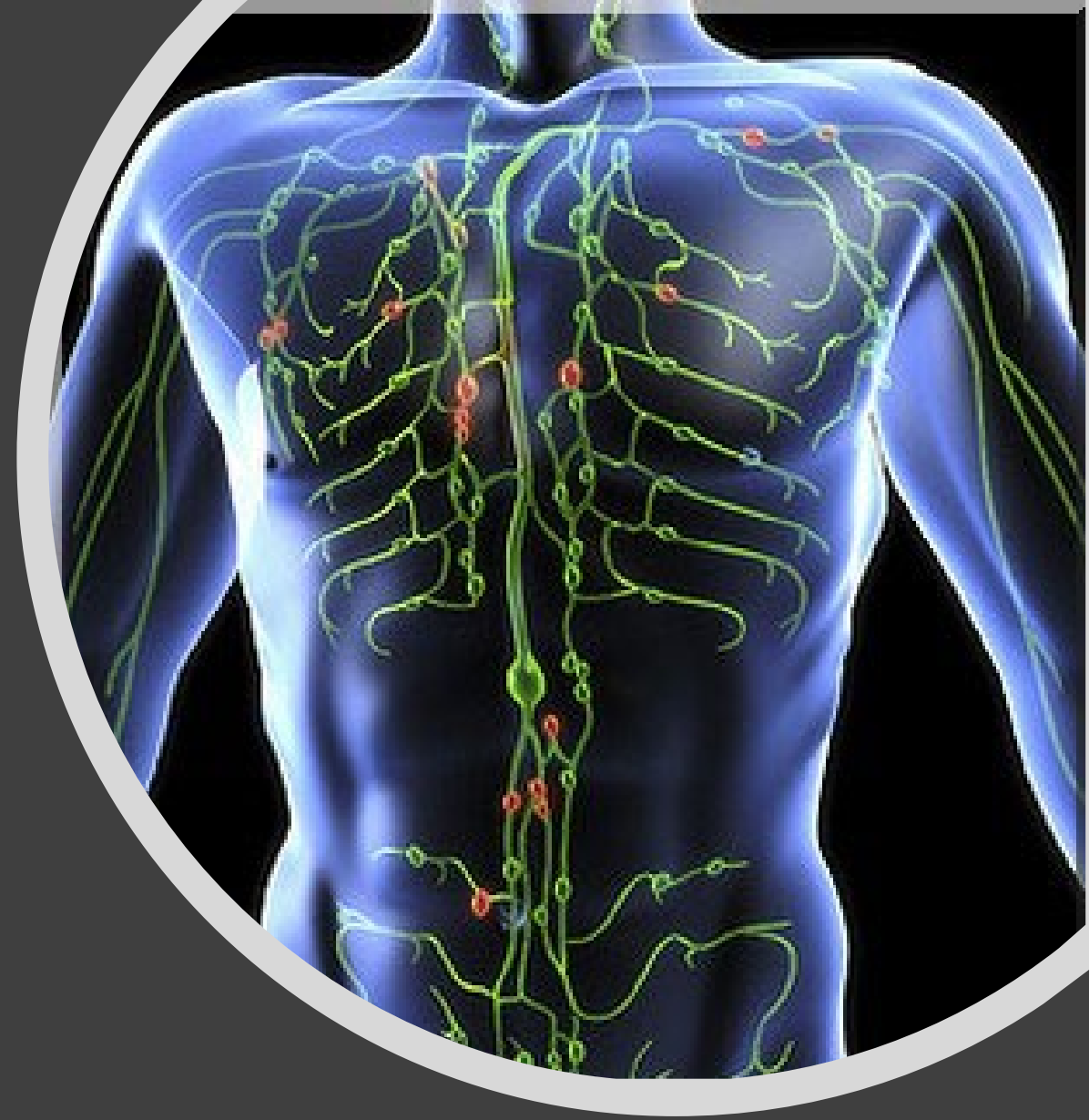
## Primary lymphoid organs

- Primary lymphoid organs include:
  - the bone marrow
  - The thymus gland
- The bone marrow and thymus are the locations where lymphocytes of the adaptive immune system proliferate and mature.



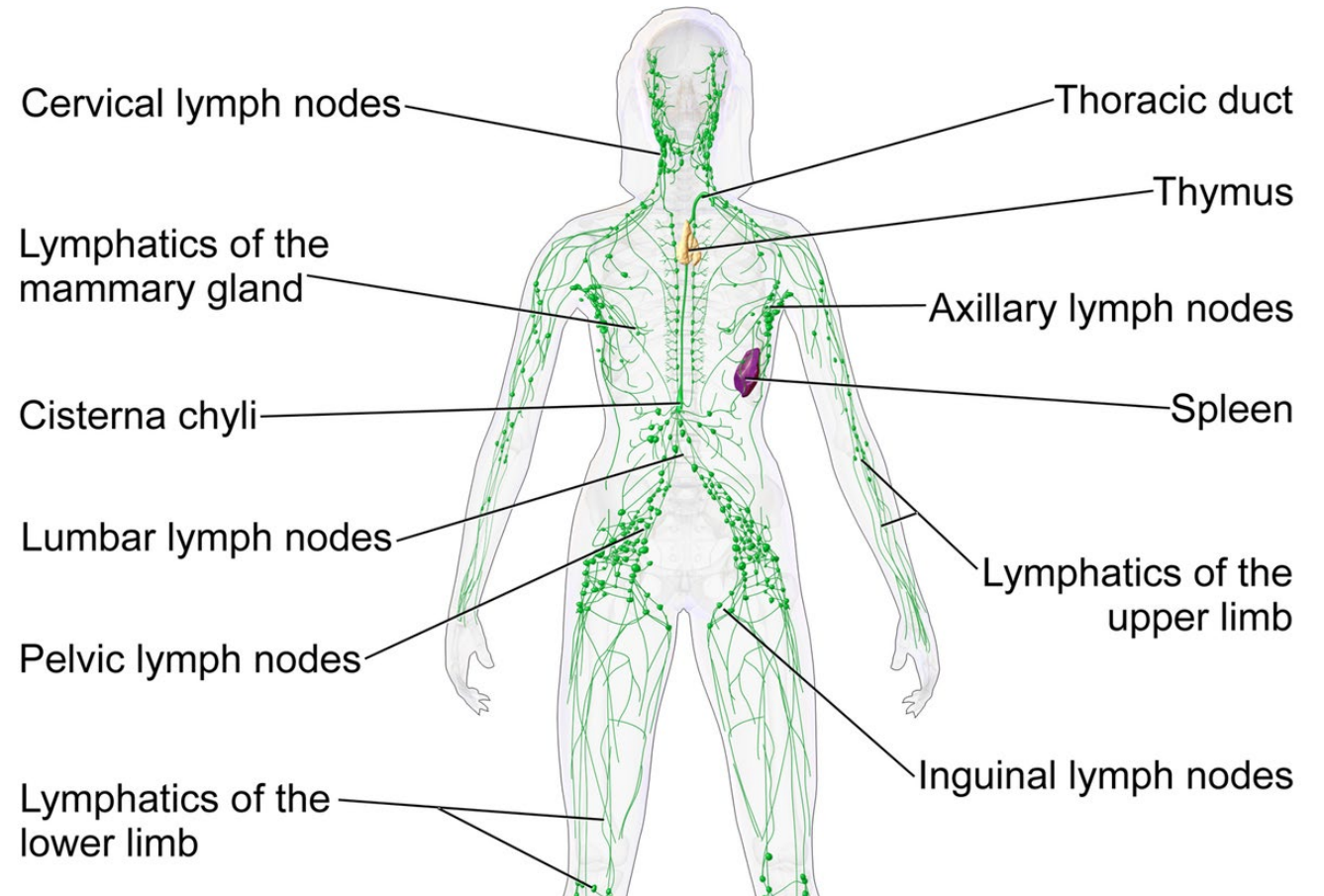
## lymphatic fluid

- Lymph or lymphatic fluid is the term used to describe interstitial fluid once it has entered the lymphatic system.



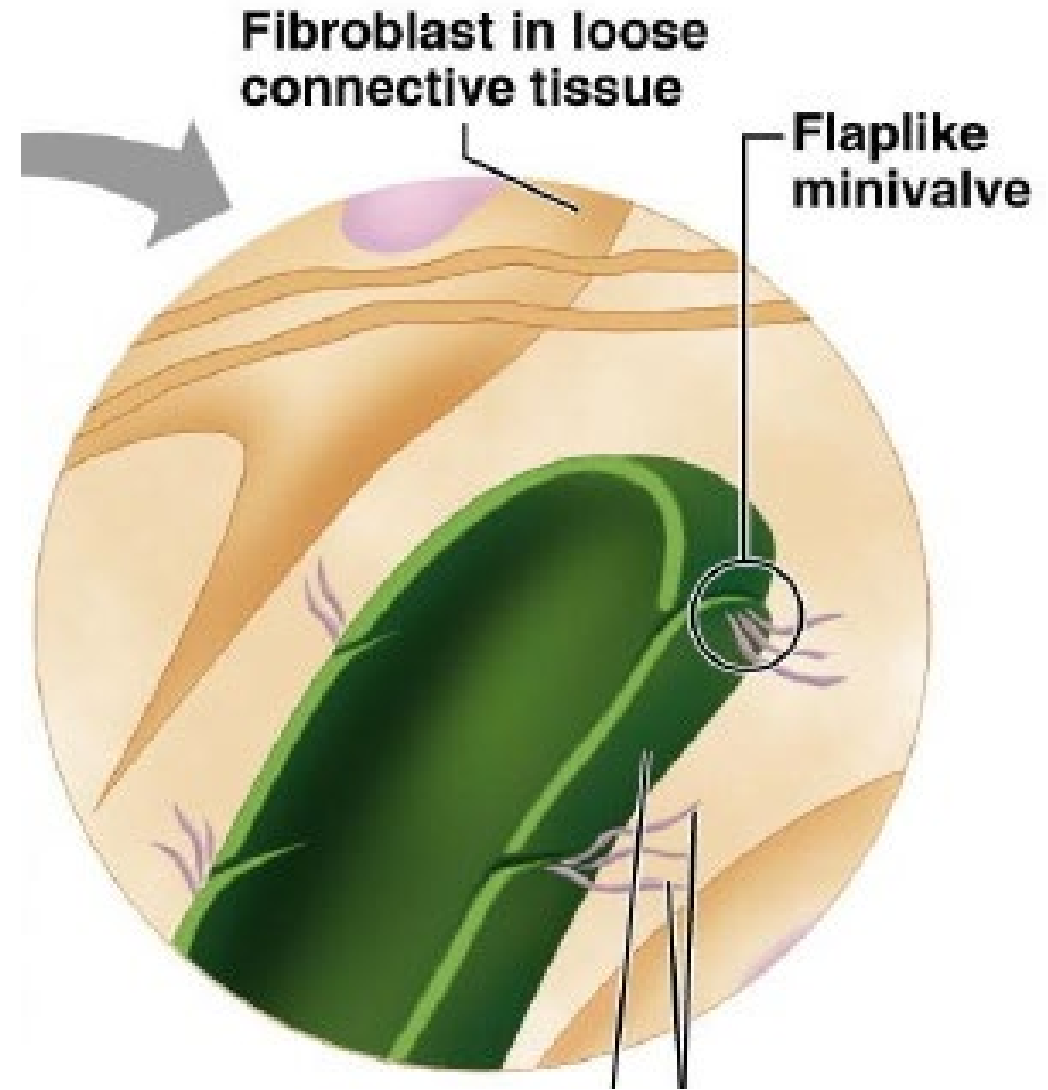
# lymph nodes

- Cells of the immune system also use lymph nodes as major staging areas for the development of critical immune responses.
- A lymph node is one of the small, bean-shaped organs located throughout the lymphatic system.
- the lymph nodes, which are commonly found near the groin, armpits, neck, chest, and abdomen.

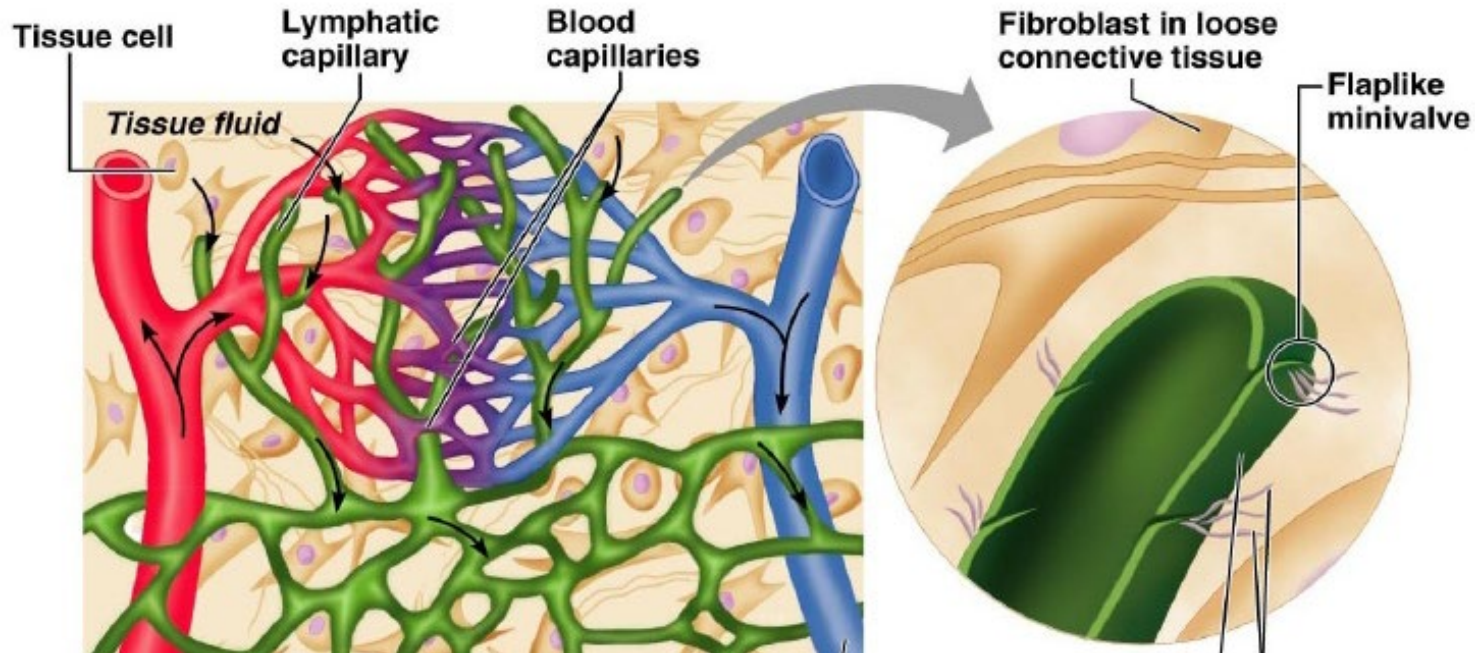


## Lymphatic Capillaries

- lymph is not actively pumped by the heart
- lymph is forced through the vessels by...
  - the movements of the body- the contraction of skeletal muscles during body movements, and breathing.
  - One-way valves (semi-lunar valves) in lymphatic vessels keep the lymph moving toward the heart.

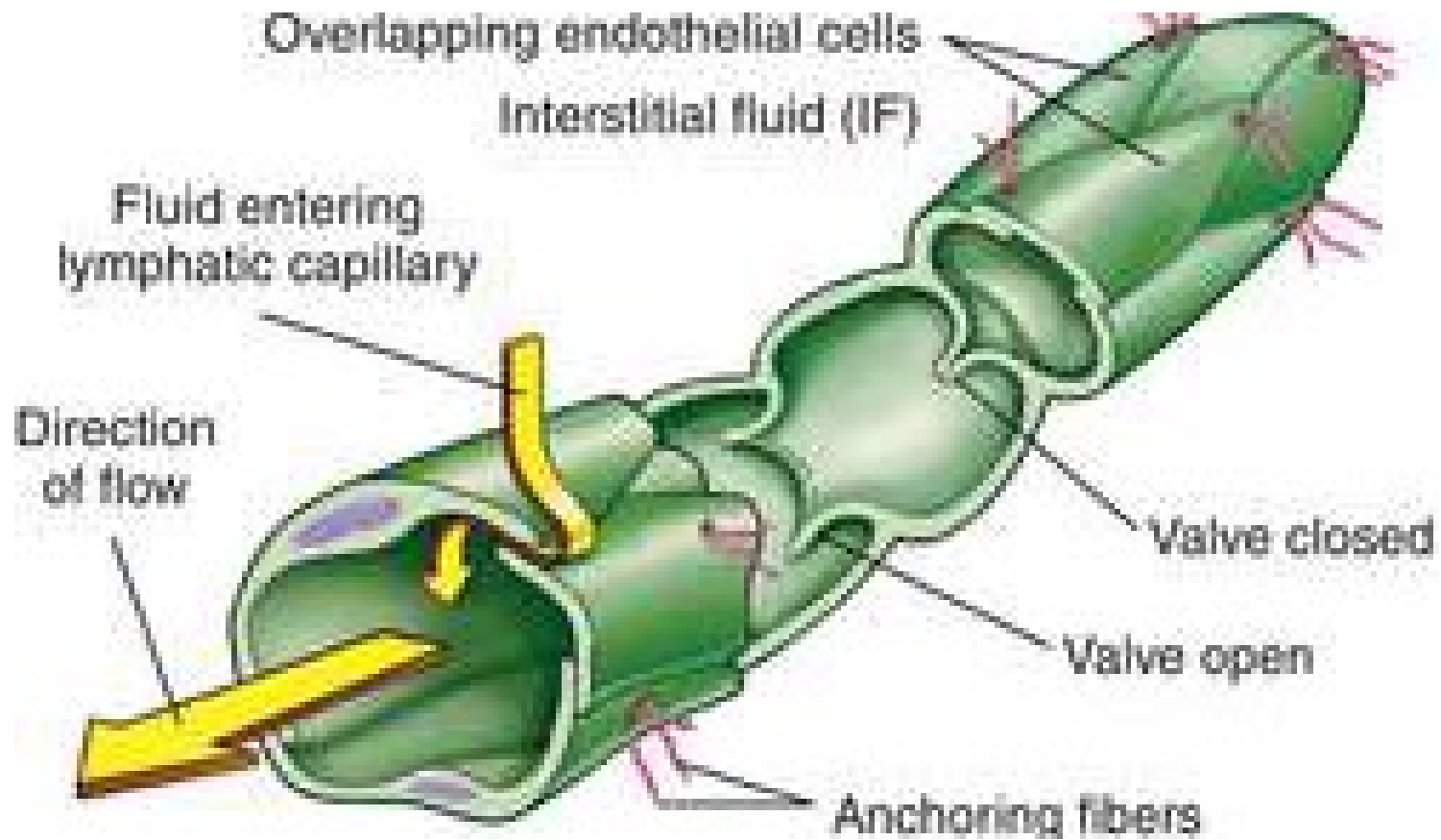


# Lymphatic Capillaries



- Lymphatic capillaries, also called the terminal lymphatics, are vessels where interstitial fluid enters the lymphatic system to become lymph fluid.
- Lymphatic capillaries are interlaced among the arterioles and venules of the circulatory system in the soft connective tissues of the body.

Lymphatic Capillaries

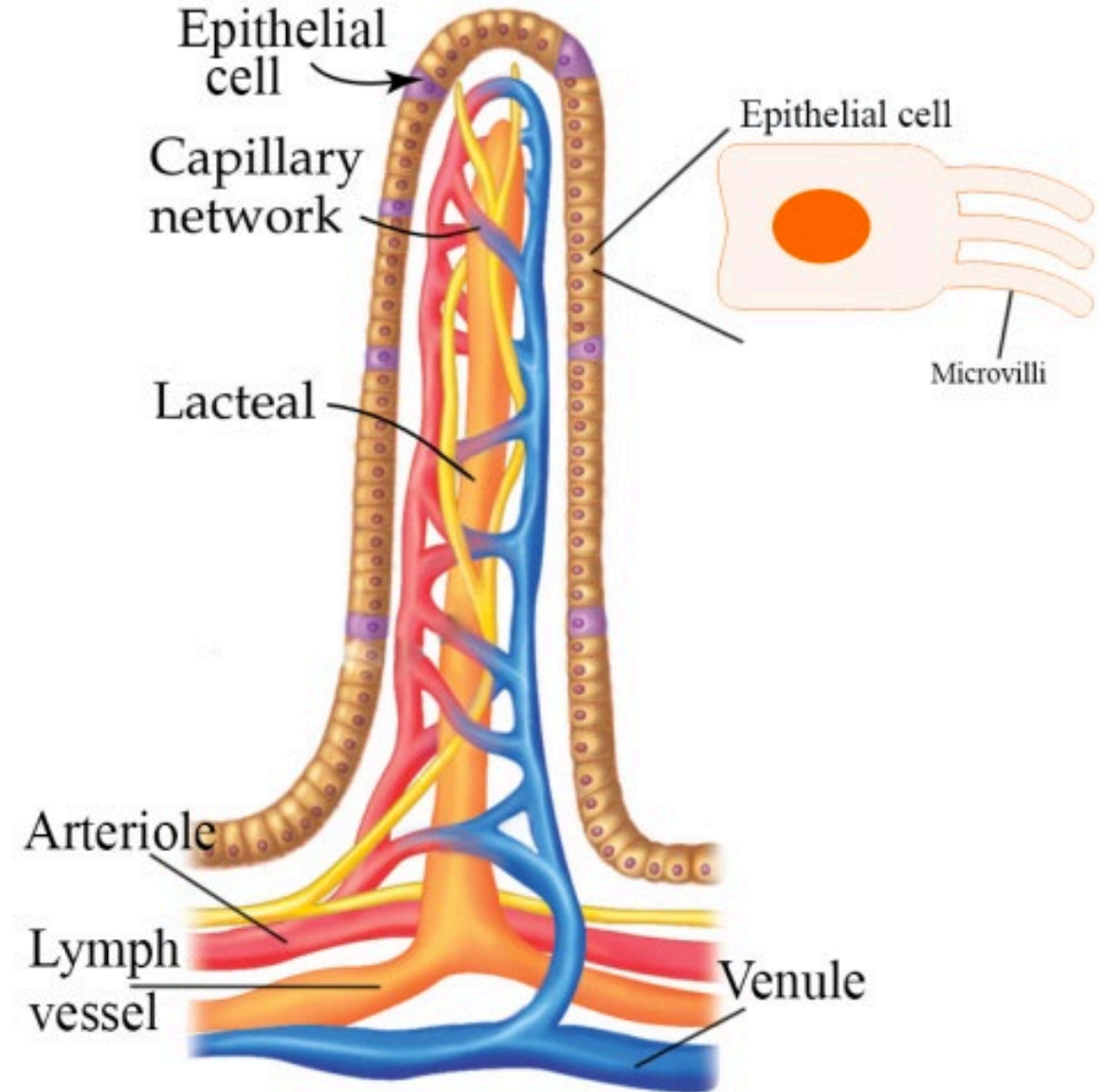


## Lymphatic capillaries

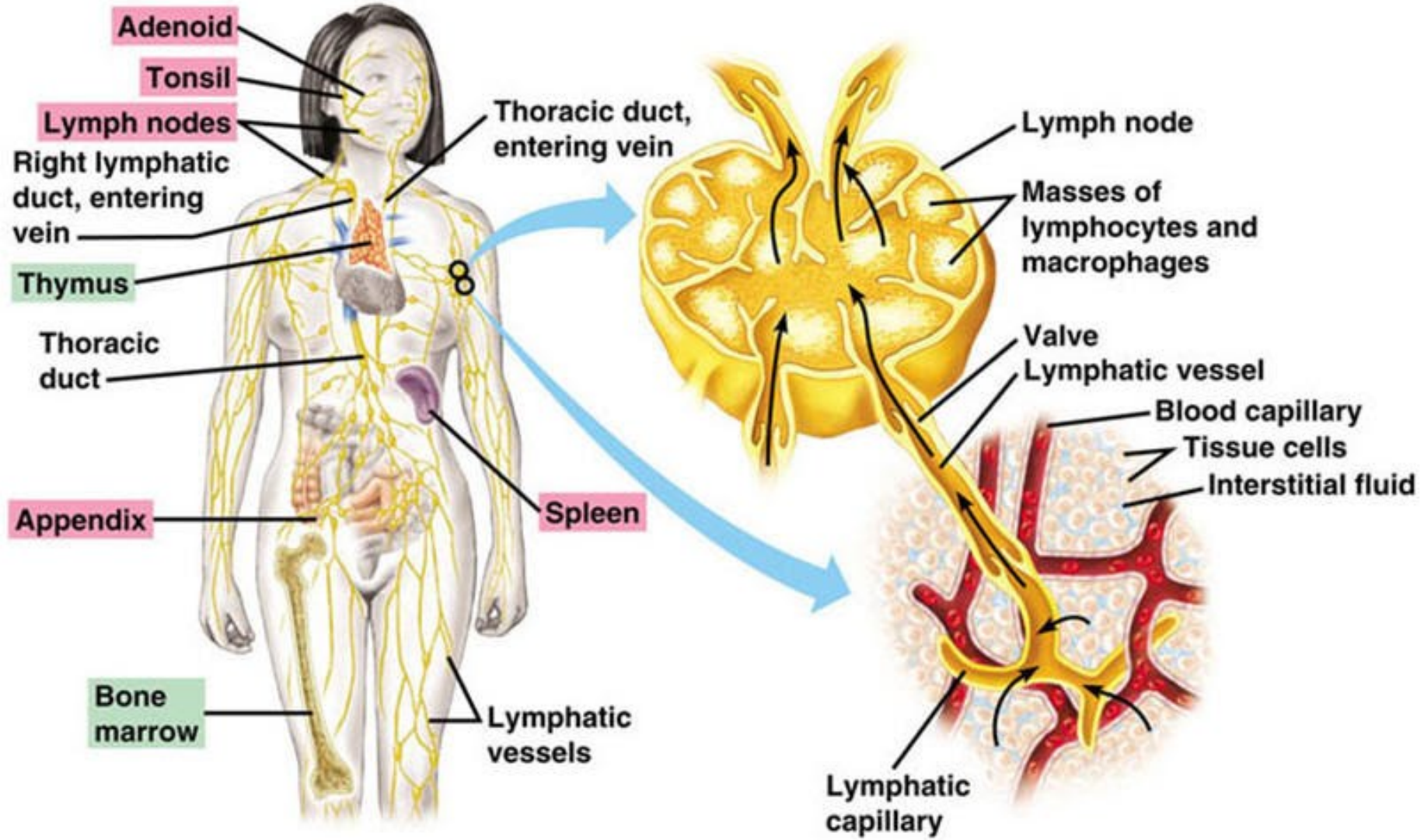
- Lymphatic capillaries are formed by a one cell-thick layer of endothelial cells.
- interstitial fluid flows into lymphatic capillaries via overlapping cells.
- When interstitial pressure is low, the endothelial flaps close to prevent “backflow.”

# lacteals

- In the small intestine, lymphatic capillaries called lacteals are critical for the transport of dietary lipids and lipid-soluble vitamins to the bloodstream.
- In the small intestine, dietary triglycerides combine with other lipids and proteins, and enter the lacteals to form a milky fluid called chyle.
- The chyle then travels through the lymphatic system, eventually entering the liver and then the bloodstream.



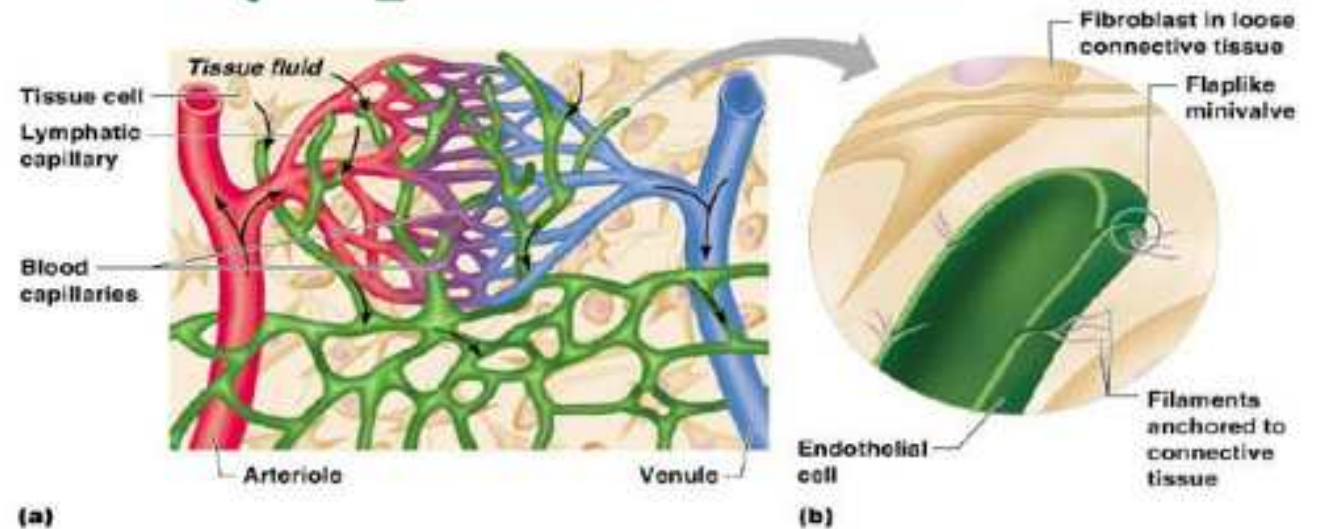


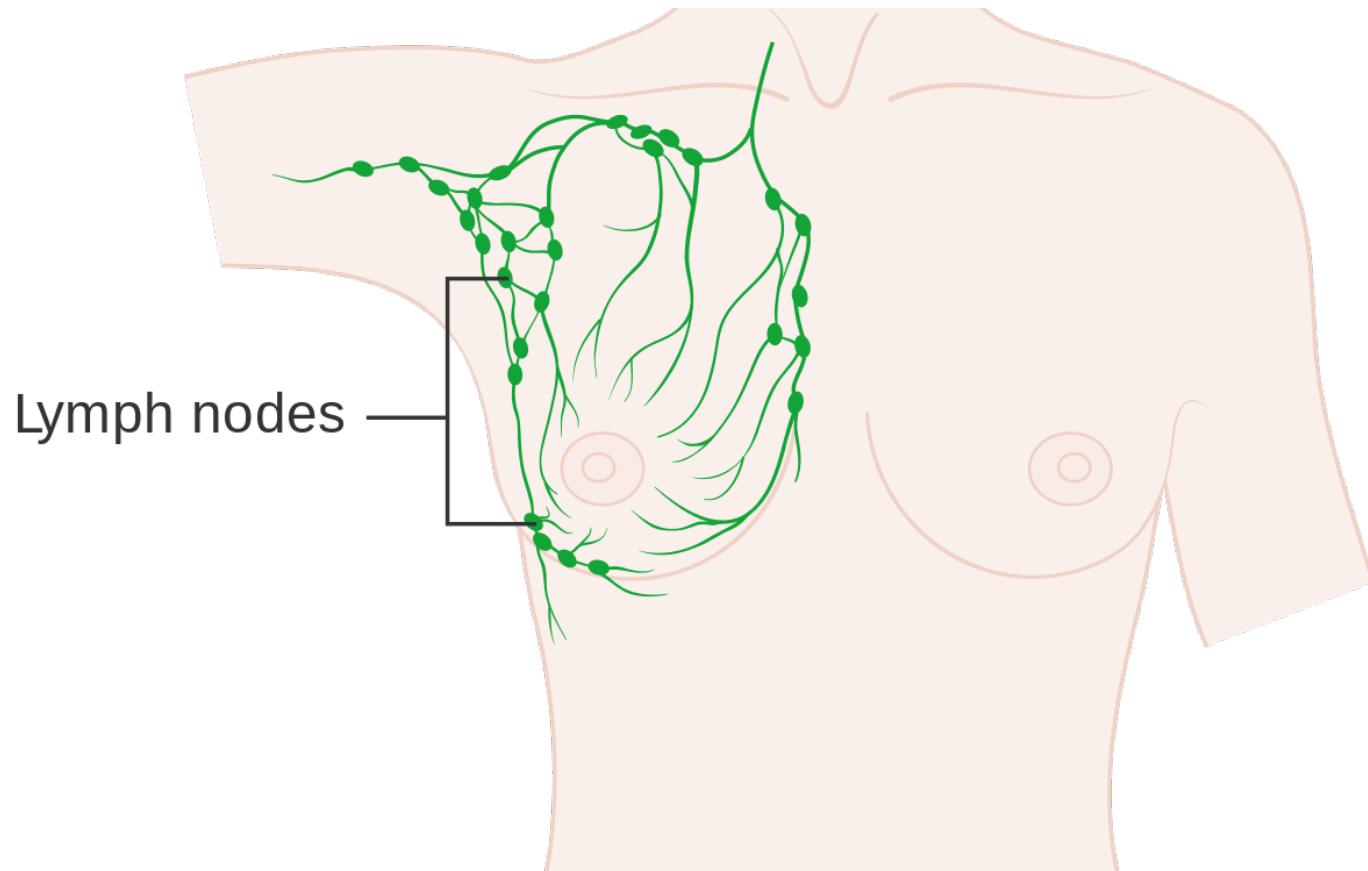


## lymphatic vessels - Transport

- the network of lymphatic vessels transports...
  - cells of the immune system
  - lipids
  - fat-soluble vitamins

## Lymphatic Vessel

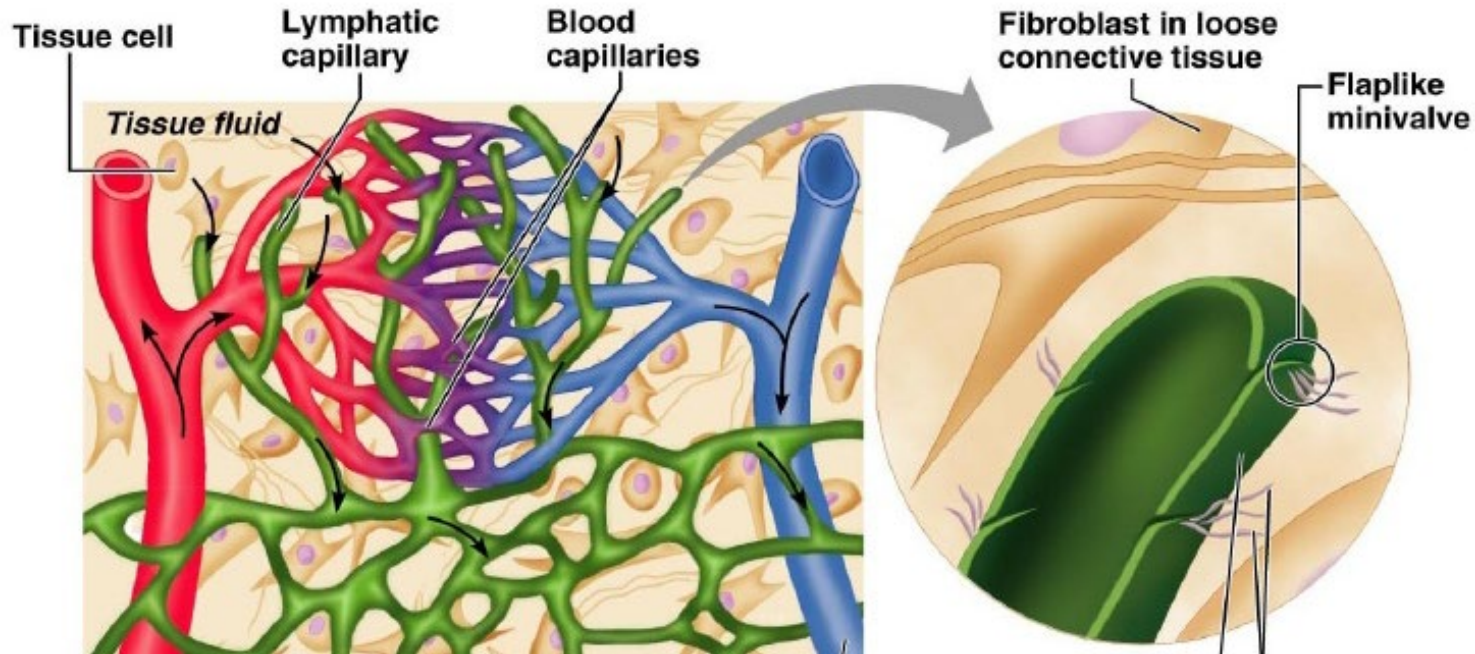




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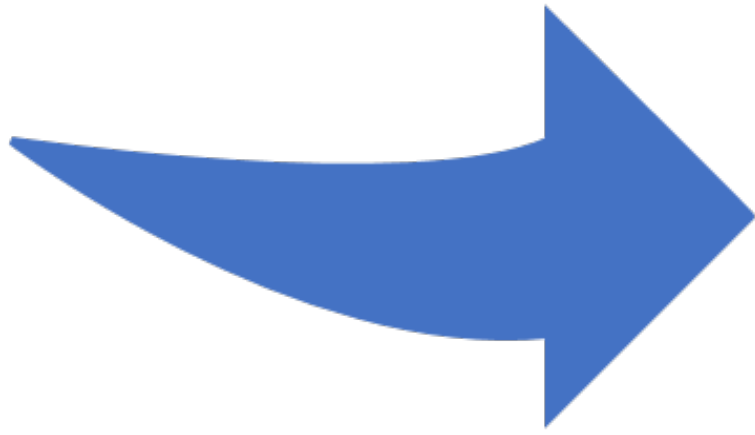
lymph nodes

# Lymphatic Capillaries



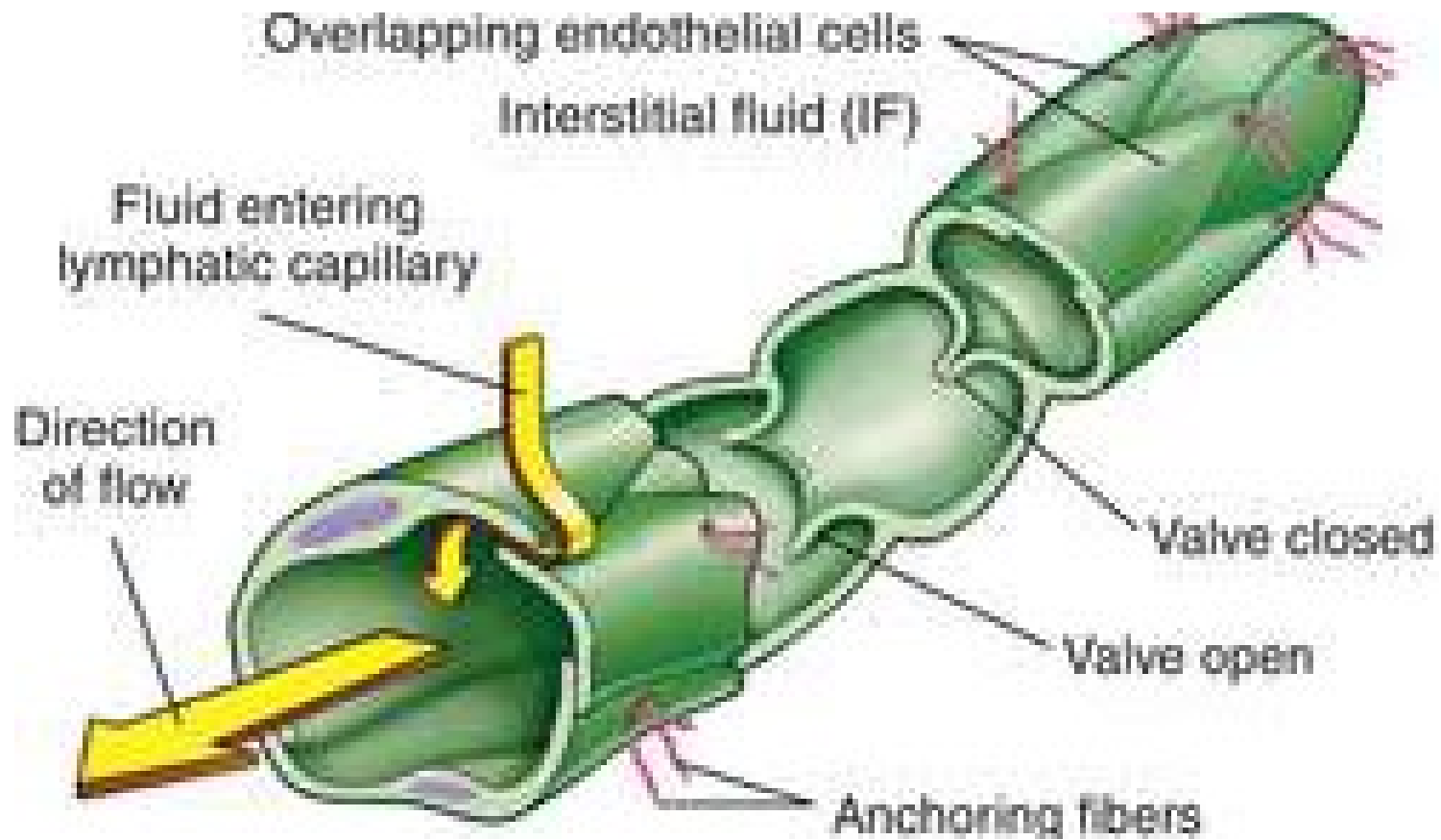
- The lymphatic vessels begin as capillaries, which feed into larger and larger lymphatic vessels, and eventually empty into the bloodstream by a series of ducts.

Lymphatic Vessels



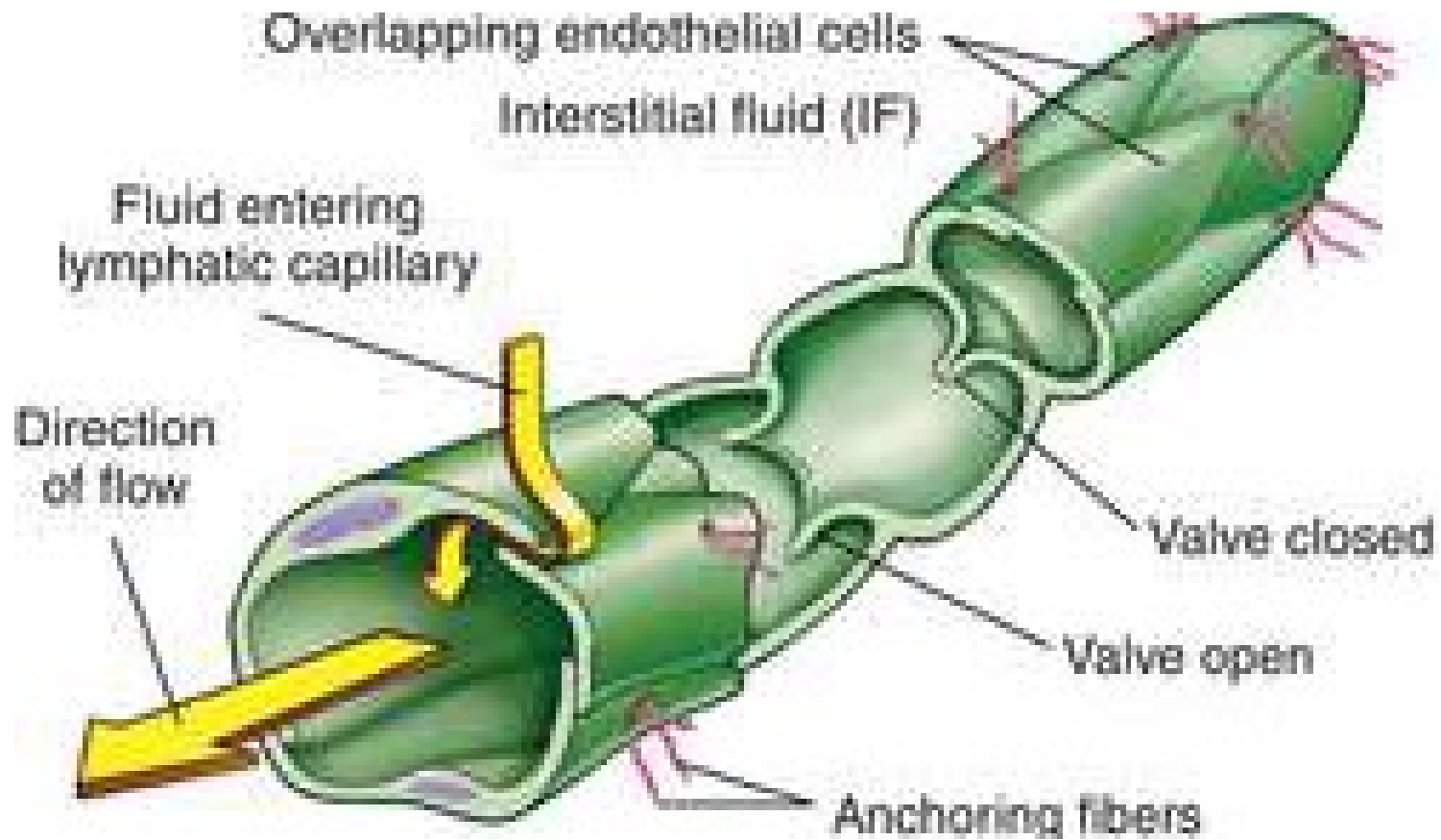
# Lymphatic Capillaries

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- lymph is forced through the vessels by...
  - the movements of the body- the contraction of skeletal muscles during body movements, and breathing.
  - One-way valves (semi-lunar valves) in lymphatic vessels keep the lymph moving toward the heart.
  - Lymph flows from the lymphatic capillaries, through lymphatic vessels, and then is dumped into the circulatory system via the lymphatic ducts located at the junction of the jugular and subclavian veins in the neck.



## Lymphatic Capillaries

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- vessels are interlaced among the arterioles and venules of the circulatory system in the soft connective tissues of the body.

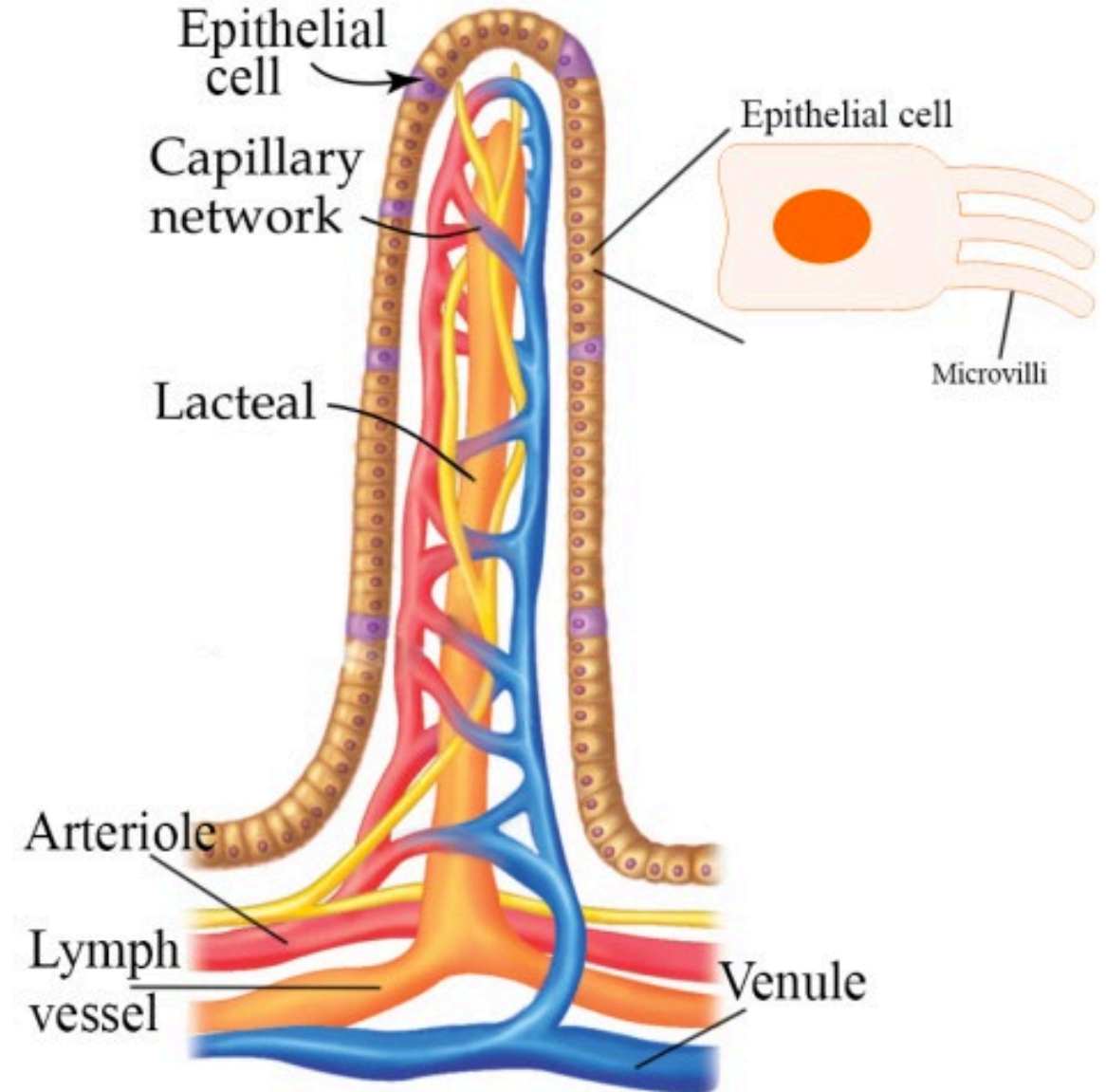


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## Larger Lymphatic Vessels, Trunks, and Ducts

- The lymphatic capillaries empty into larger lymphatic vessels, which are similar to veins in terms of their structure and the presence of valves.

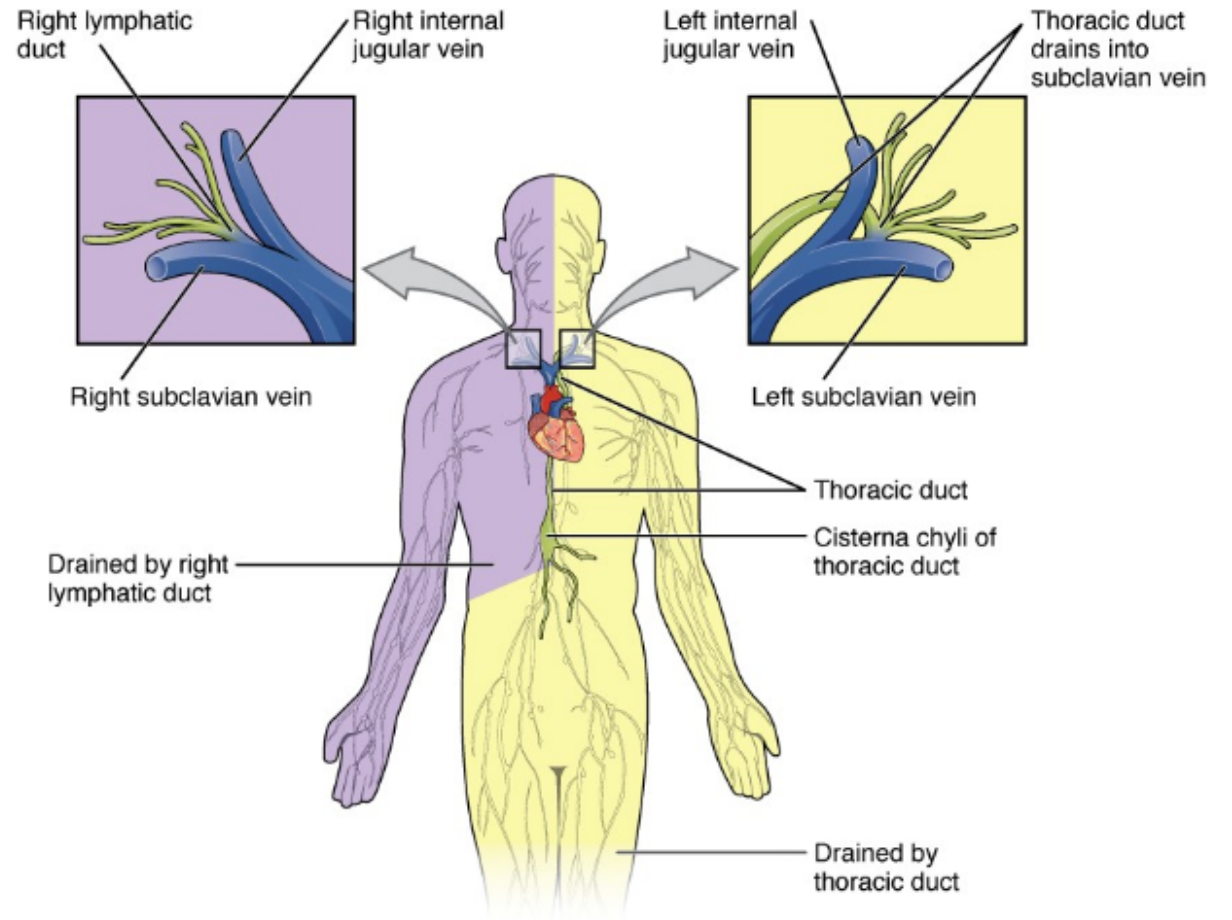
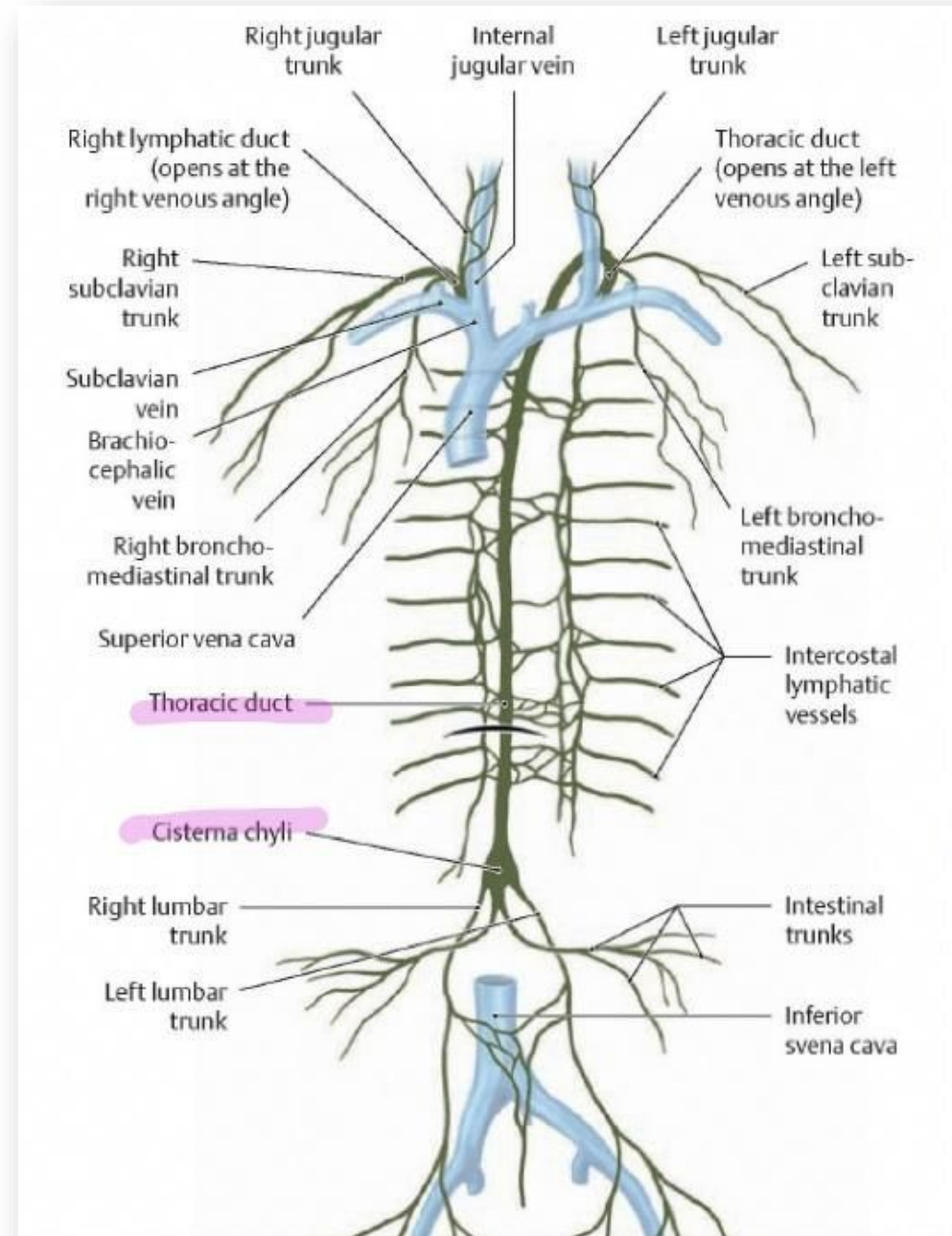
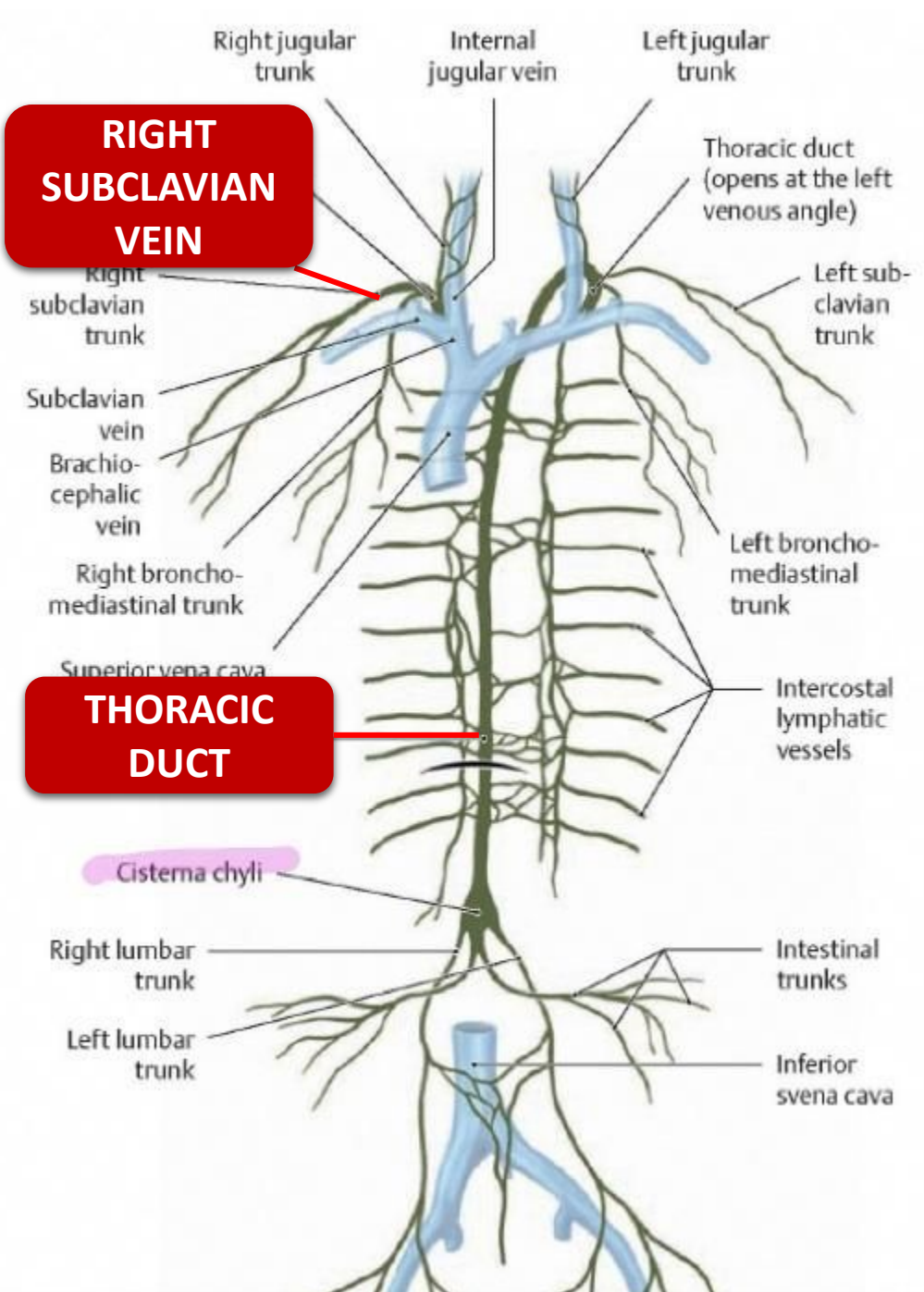


Figure 3. The thoracic duct drains a much larger portion of the body than does the right lymphatic duct.

## Larger Lymphatic Vessels, Trunks, and Ducts

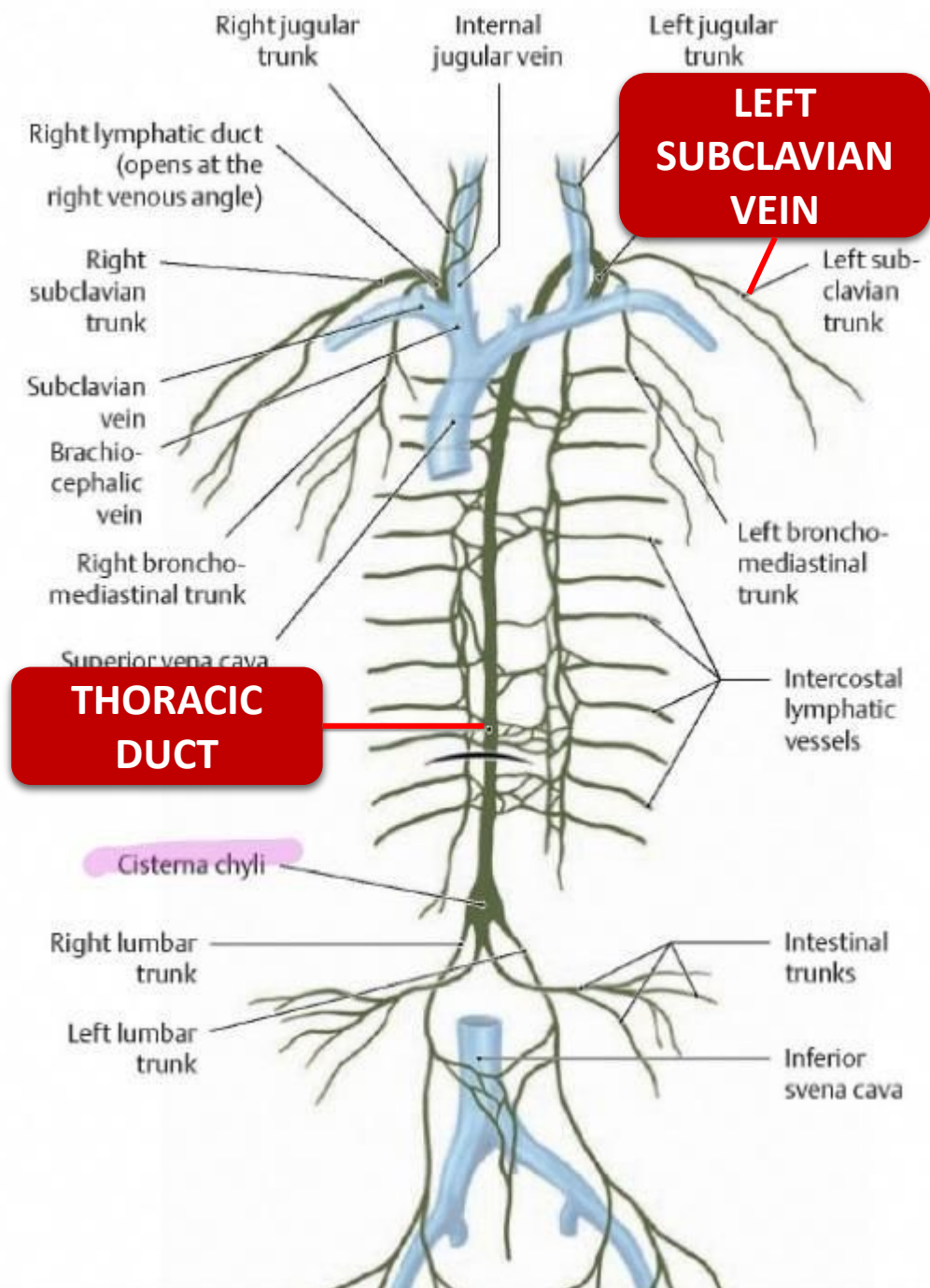
- The superficial and deep lymphatics eventually merge to form larger lymphatic vessels known as lymphatic trunks.





# Larger Lymphatic Vessels, Trunks, and Ducts

- On the right side of the body, the right sides of the head, thorax, and right upper limb drain lymph fluid into the right subclavian vein via the right lymphatic duct.

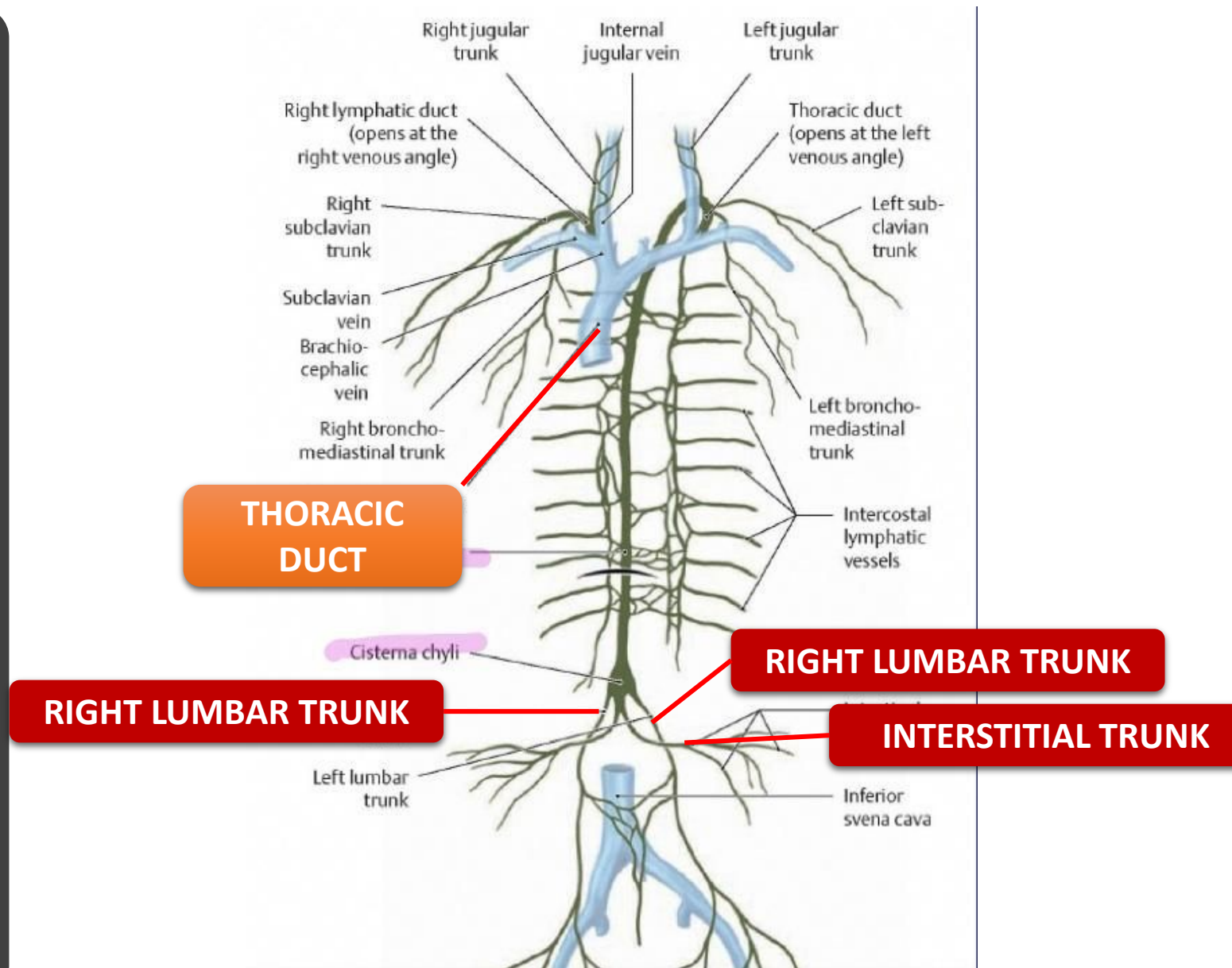


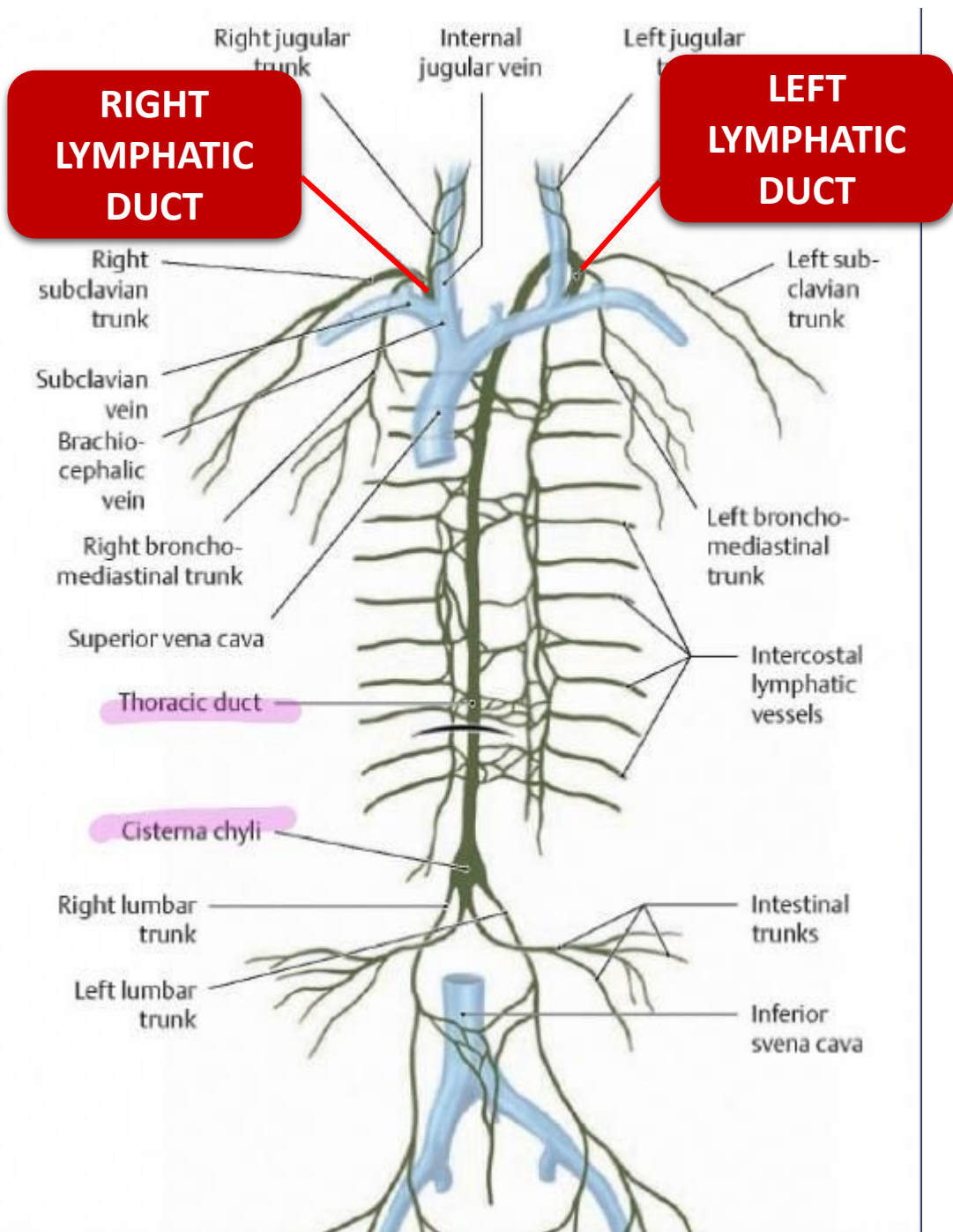
## Larger Lymphatic Vessels, Trunks, and Ducts

- On the left side of the body, the remaining portions of the body drain into the larger thoracic duct, which drains into the left subclavian vein.

## Larger Lymphatic Vessels, Trunks, and Ducts

- The thoracic duct begins beneath the diaphragm
- receives lymph from the lower abdomen, pelvis, and lower limbs by way of the left and right lumbar trunks and the intestinal trunk.





# Asymmetrical Lymphatic Drainage

- The overall drainage system of the body is asymmetrical.
  - The right lymphatic duct receives lymph from only the upper right side of the body.
  - The lymph from the rest of the body enters the bloodstream through the thoracic duct via all the remaining lymphatic trunks.
    - *In general, lymphatic vessels of the subcutaneous tissues of the skin, that is, the superficial lymphatics, follow the same routes as veins, whereas the deep lymphatic vessels of the viscera generally follow the paths of arteries.*



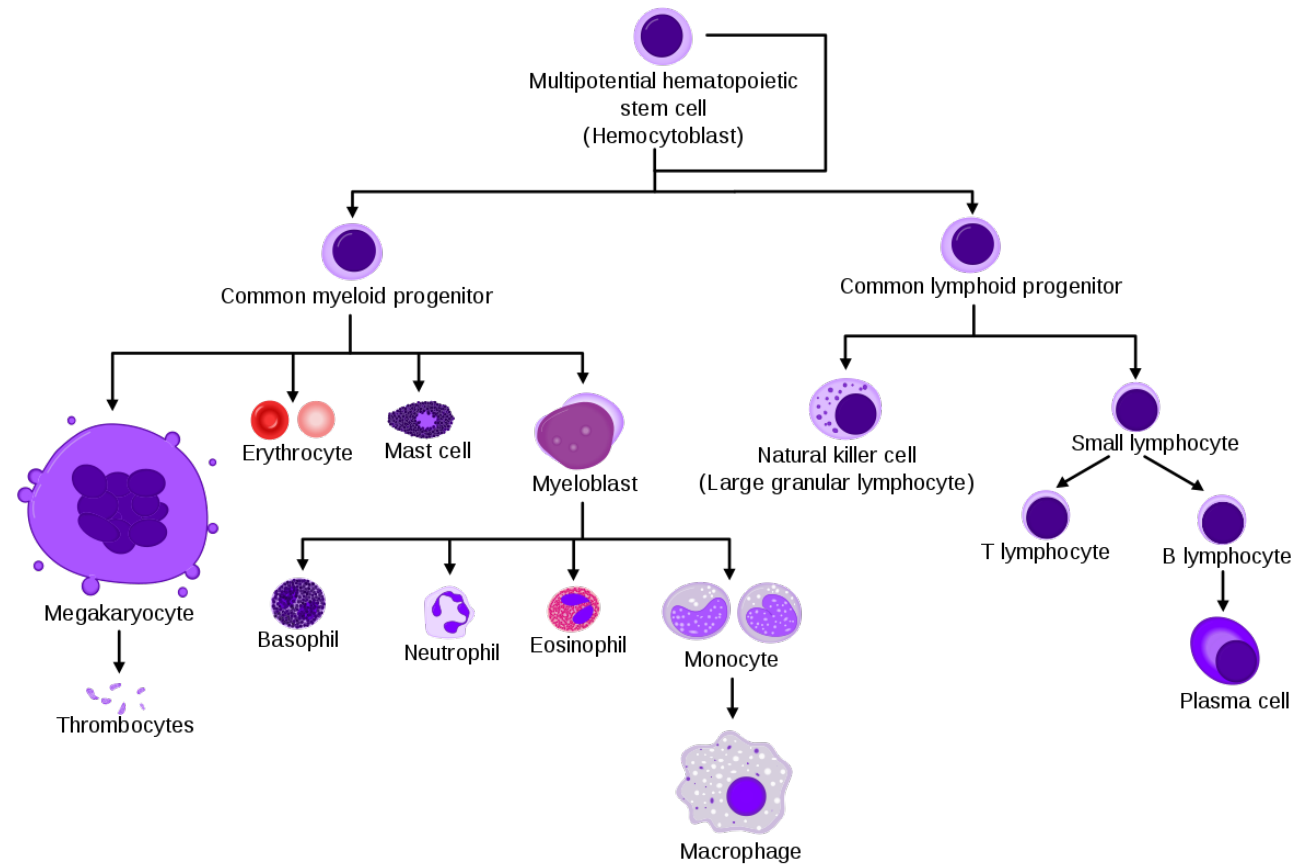
# The Organization of Immune Function

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- The immune system has 3 levels of defense against illness and disease.
  - **1<sup>st</sup> line of defense** - Barrier defenses: skin and mucous membranes
  - **2<sup>nd</sup> line of defense** - Nonspecific innate immune response
    - Fast-acting
    - Generalized non-specific attack
  - **3<sup>rd</sup> line of defense** - Adaptive immune response
    - Slow-acting
    - Very specific

# White Blood Cells (Leukocytes)

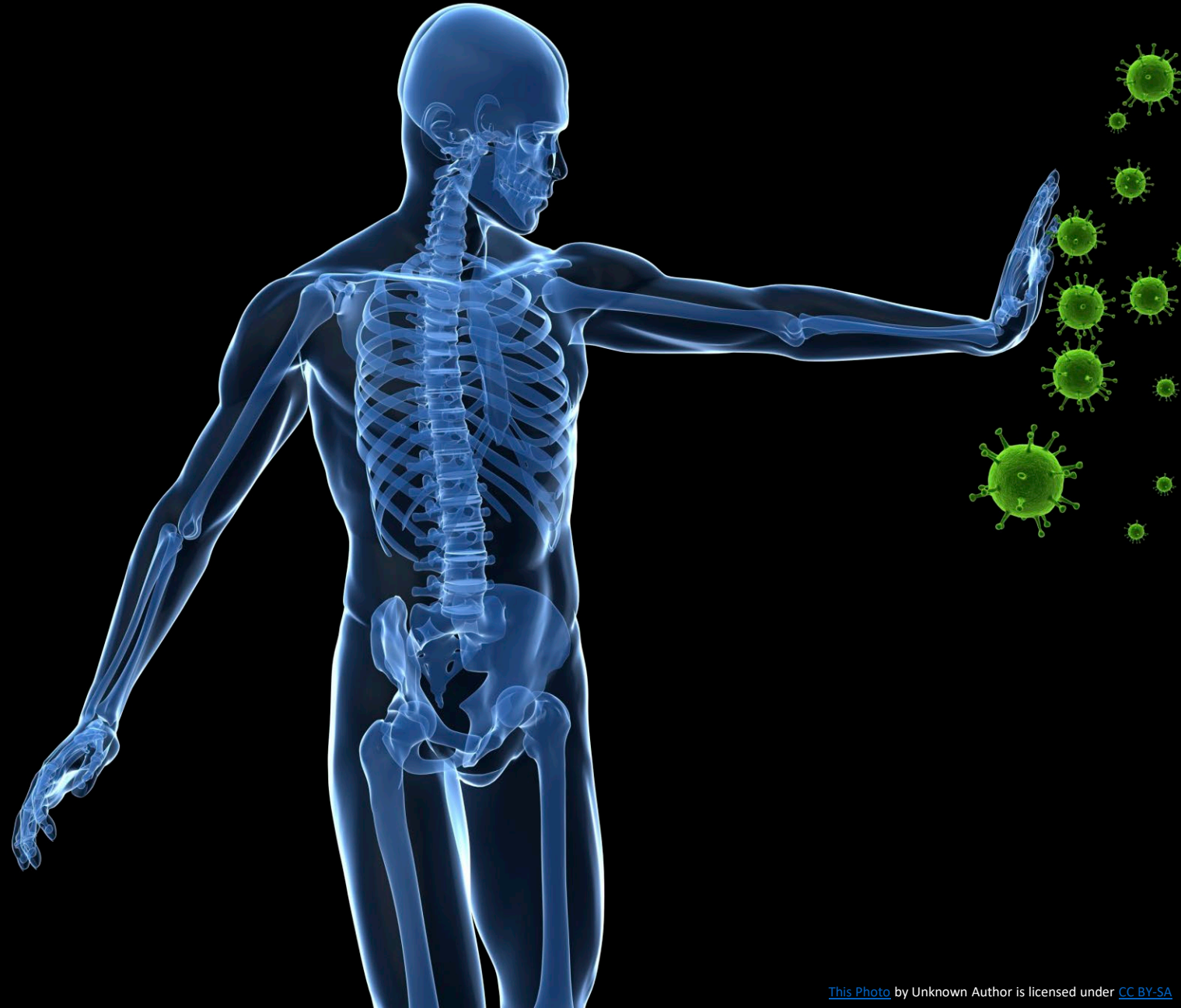
Cells of the immune  
and lymphatic **system**  
all come from the  
hematopoietic  
stem cells of the  
bone marrow.





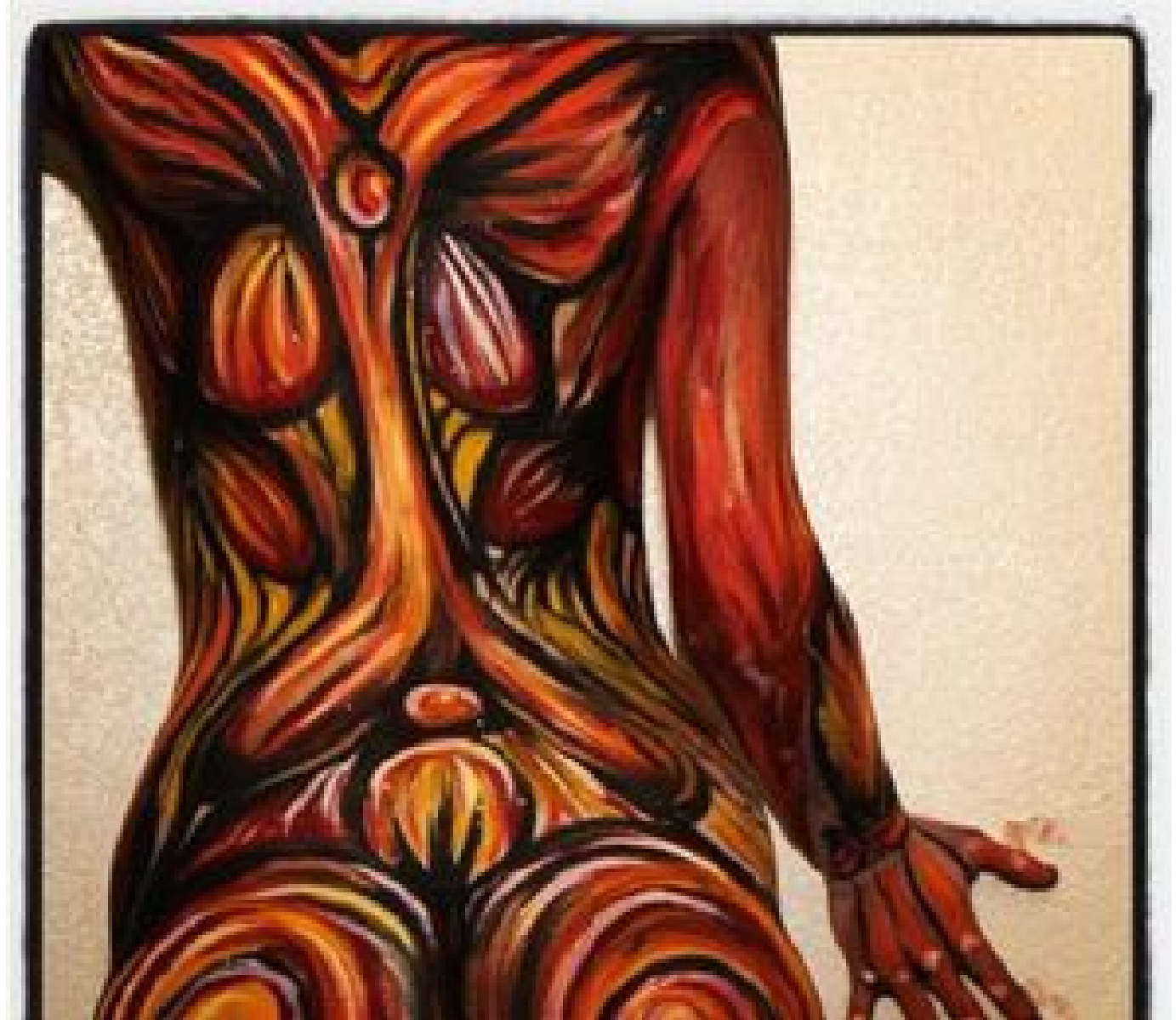
# The Functions of the Immune System

1. Scavenge dead, dying body cells
2. Destroy abnormal (cancerous)
3. Protect from pathogens & foreign molecules: parasites, bacteria, viruses



# THE FIRST LINE OF DEFENSE - Prevention

The Physical and Chemical Barriers are the First Lines of Defense.



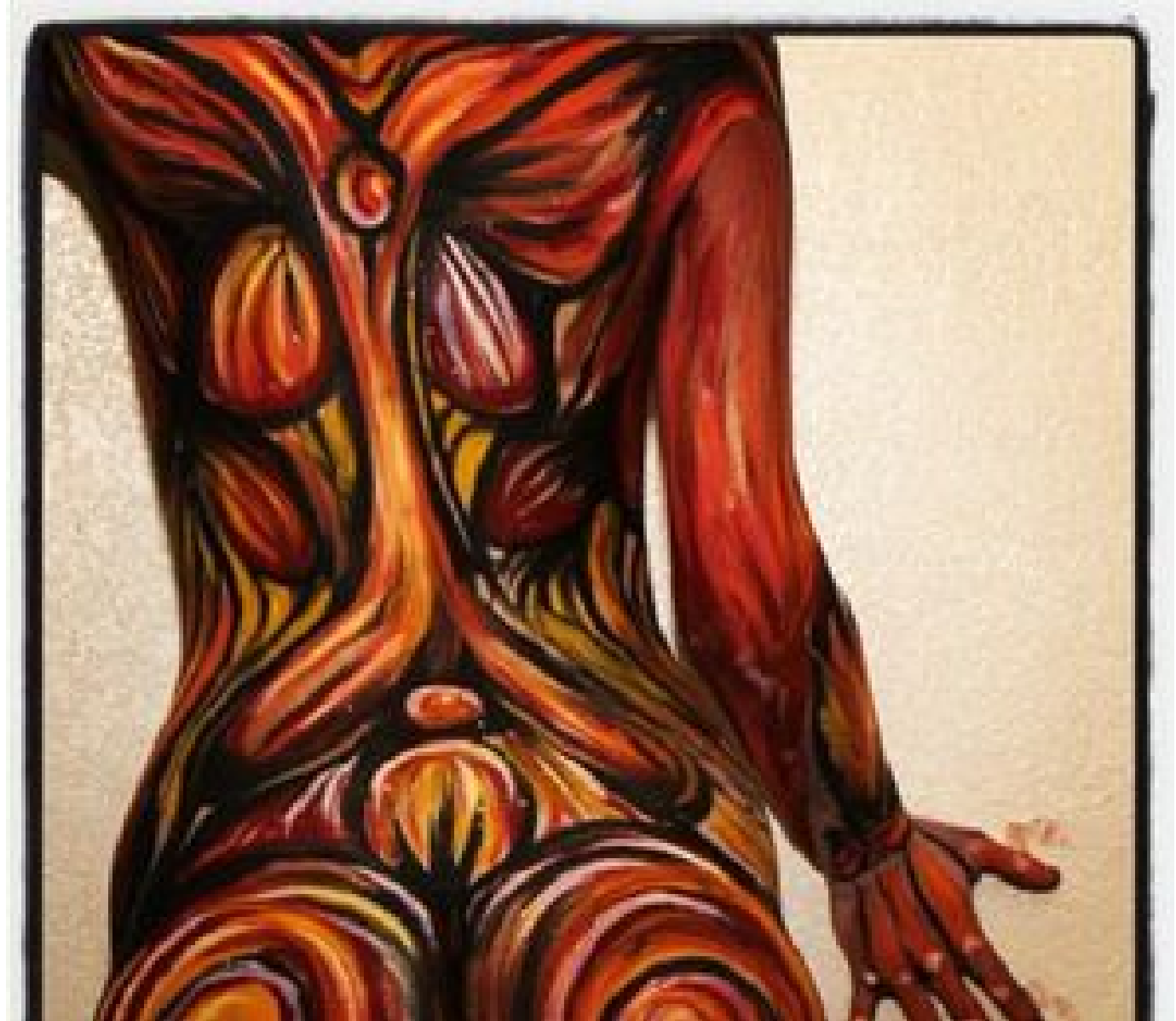
# THE FIRST LINE OF DEFENSE - Prevention

## 1. Physical Barriers of the Body

- a. Skin
- b. Mucous Membranes

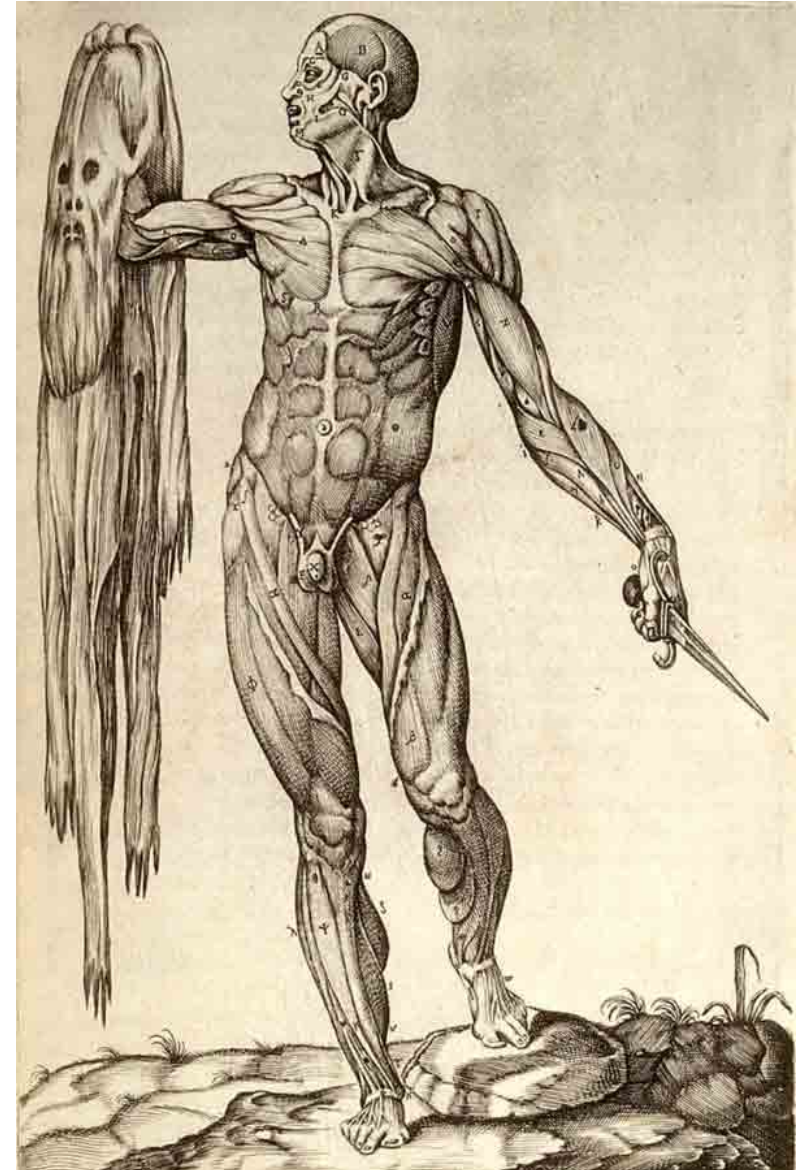
## 2. Chemical Defenses

- a. Sweat
- b. Acidic Environments
- c. Lysozyme

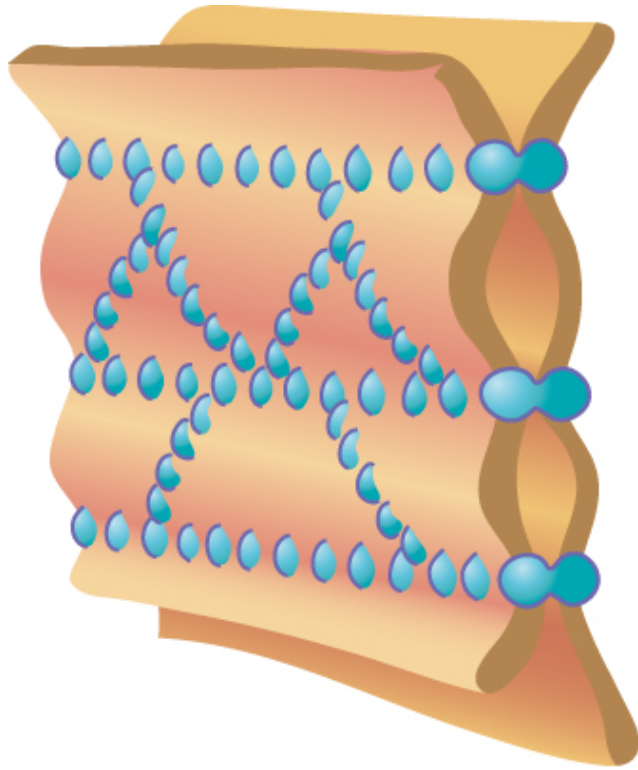


# THE SKIN

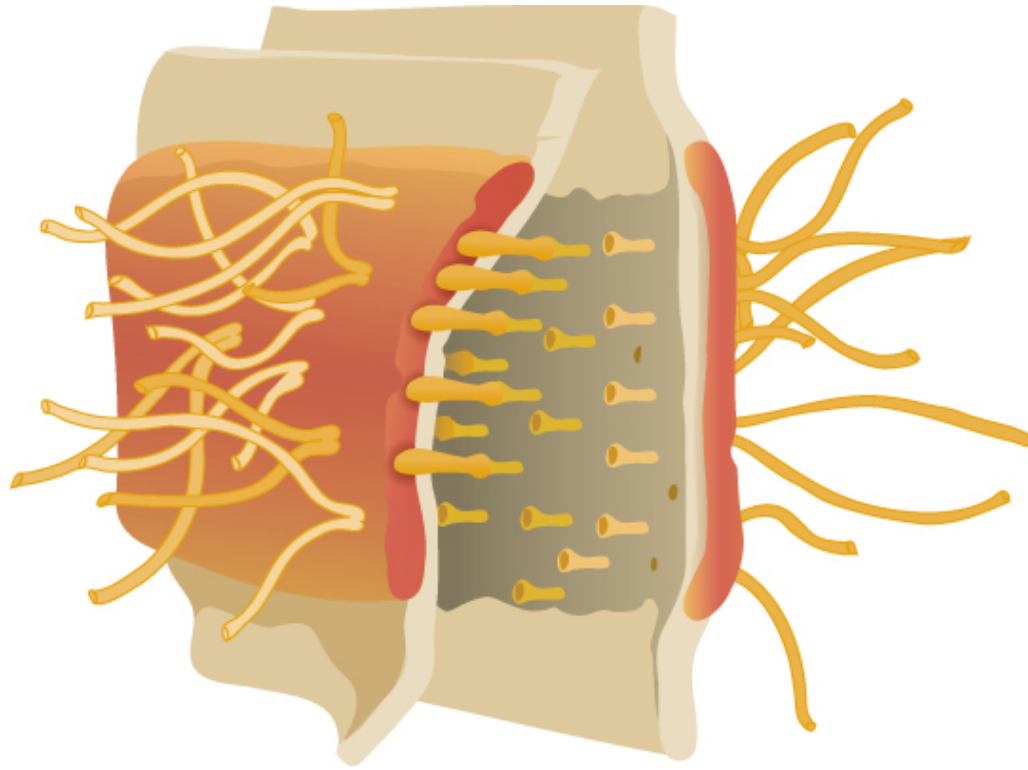
- Skin provides a physical barrier as a first line of defense against infection.
  - **bacteria and viruses cannot penetrate the tightly knit cells of the skin.**



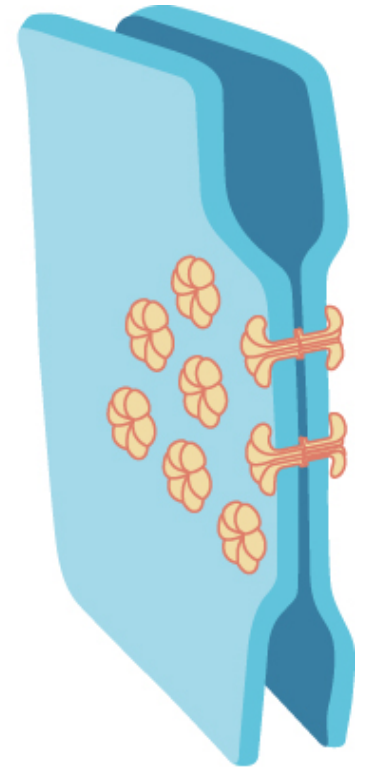
# Tight Junctions, Desmosomes and Gap Junctions Hold Epithelial Cells Tightly Together Creating a Preventative Barrier.



tight junctions



desmosomes



gap junctions

# THE FIRST LINE OF DEFENSE - Prevention

## 2 Types of Defenses

### 1. Physical Barriers of the Body

- a. ~~Skin~~
- b. Mucous Membranes

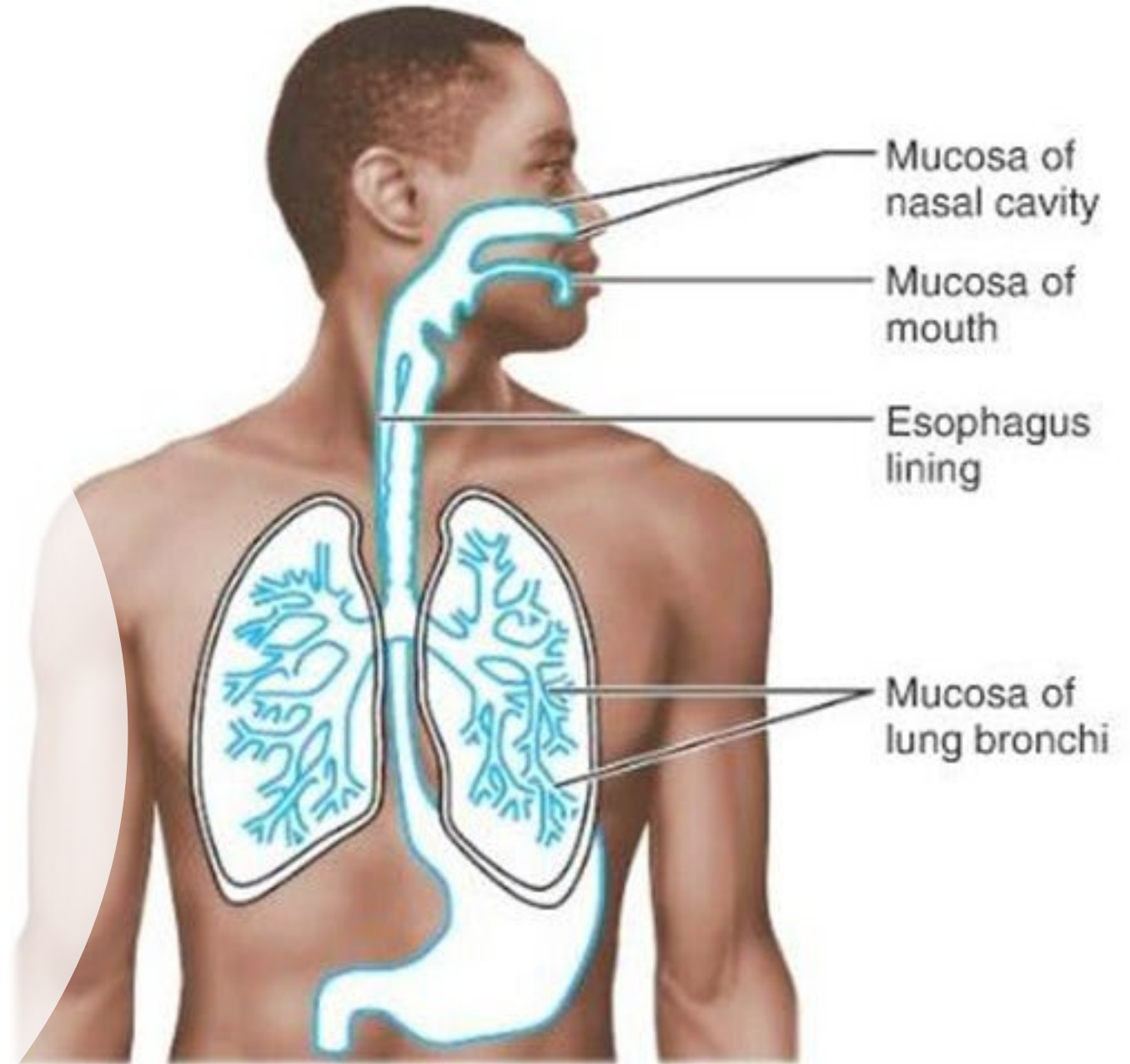
### 2. Chemical Defenses

- a. Sweat
- b. Acidic Environments
- c. Lysozyme



## Mucous membranes:

- Linings of the Respiratory System
- Linings of the Digestive System
- Urogenital Tracts
- Especially the mouth, nose, eyelids, trachea, lungs, stomach, intestines, ureters, urethra, and urinary bladder.



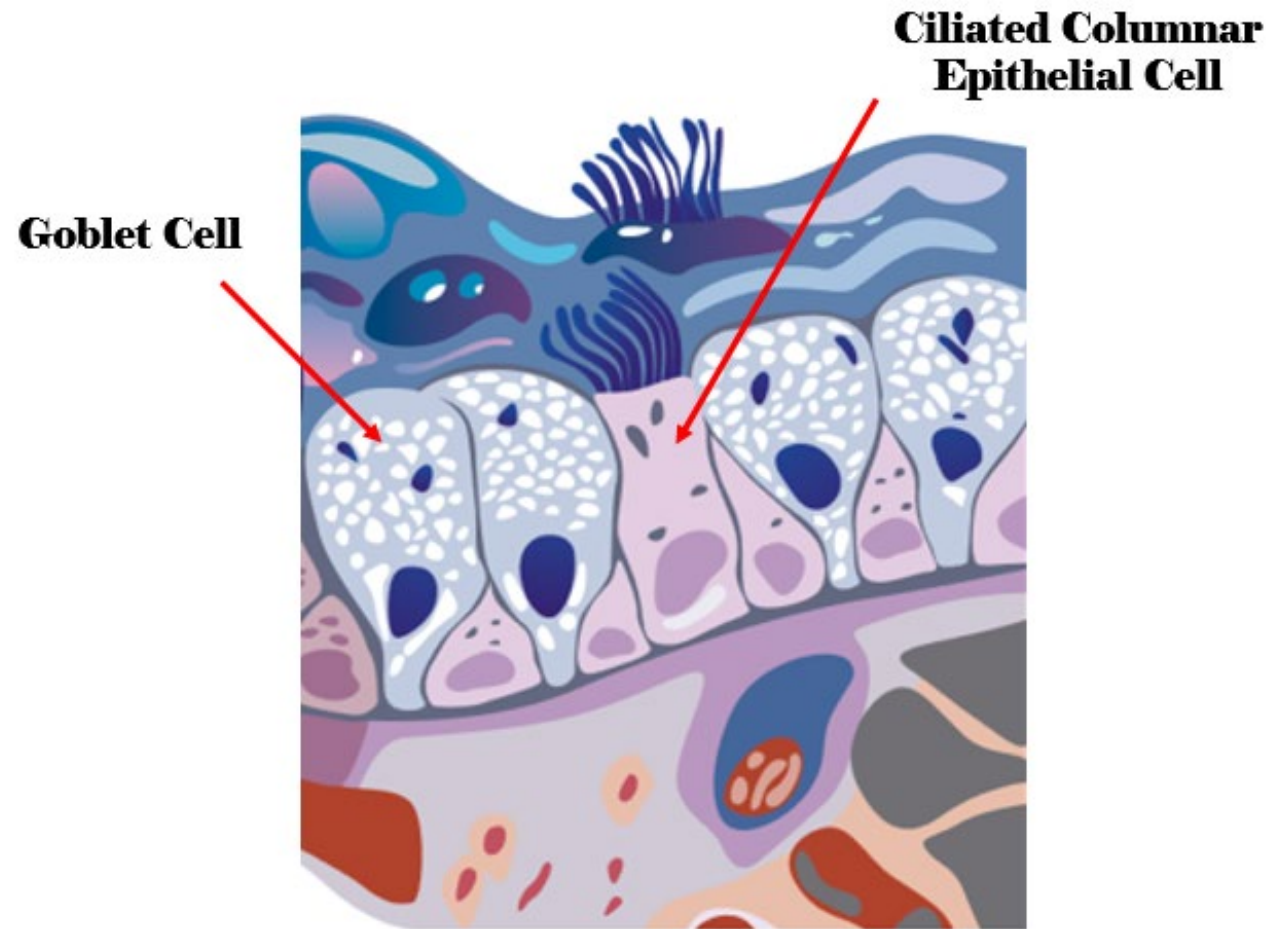
Mucous membranes are made up of **goblet cells** and **ciliated epithelial cells**.

THE GOBLET CELLS SECRETE MUCUS.

MUCUS FUNCTION TO...

- Cover And Protect Cells
- Combat Pathogens With Antimicrobial Peptides
- Trap Pathogens

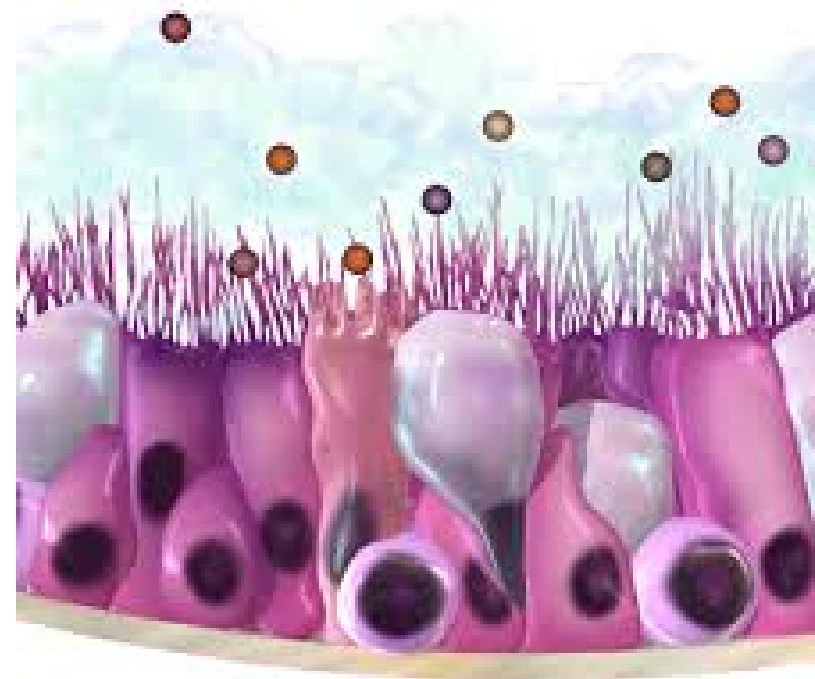
## Simple Columnar Epithelium





Mucous membranes are lined with ciliated epithelial cells.

- Cilia function to *sweep away* pathogens caught in the mucus.
- The mucus is then expelled from the body through coughing up or swallowing the pathogen and the mucus it is trapped in.



[http://www.epithelium3d.com/images/cilia-movement-2%20\(2\).gif?crc=125337232](http://www.epithelium3d.com/images/cilia-movement-2%20(2).gif?crc=125337232)

# THE FIRST LINE OF DEFENSE - Prevention

## 2 Types of Defenses

### 1. Physical Barriers of the Body

- a. ~~Skin~~
- b. ~~Mucous Membranes~~

### 2. Chemical Defenses

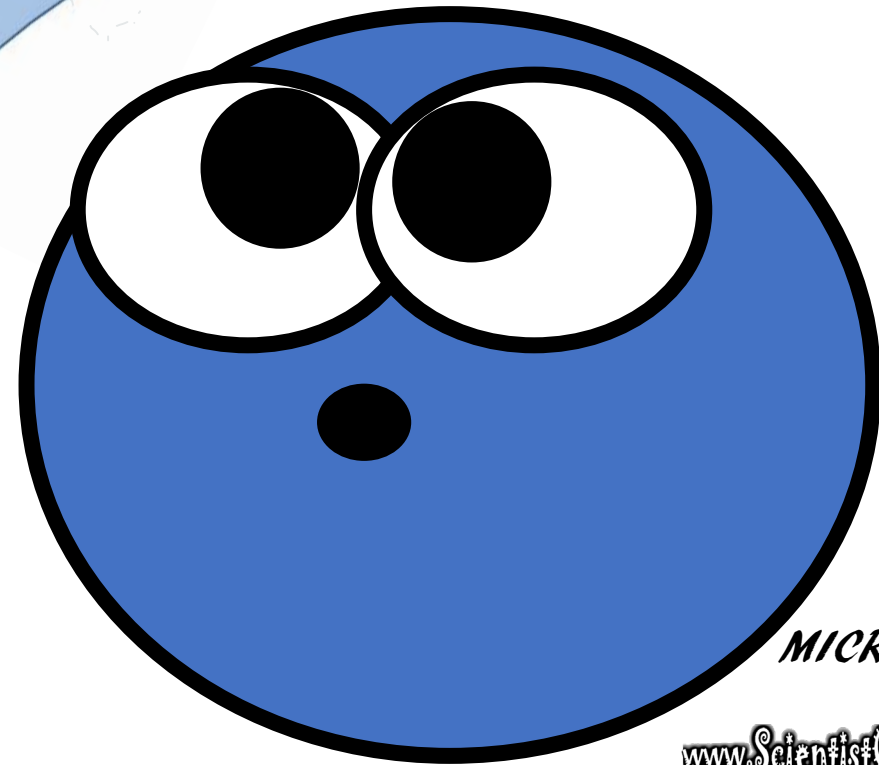
- a. Sweat
- b. Acidic Environments
- c. Lysozyme



- The skin has sweat glands that secrete sweat which has high concentrations of sodium.
- During perspiration, high levels of sodium can kill certain types of bacteria.



*The Great  
Assault of  
2012...*



*MICROBE*

[www.ScientistCindy.com](http://www.ScientistCindy.com)

# THE FIRST LINE OF DEFENSE - Prevention

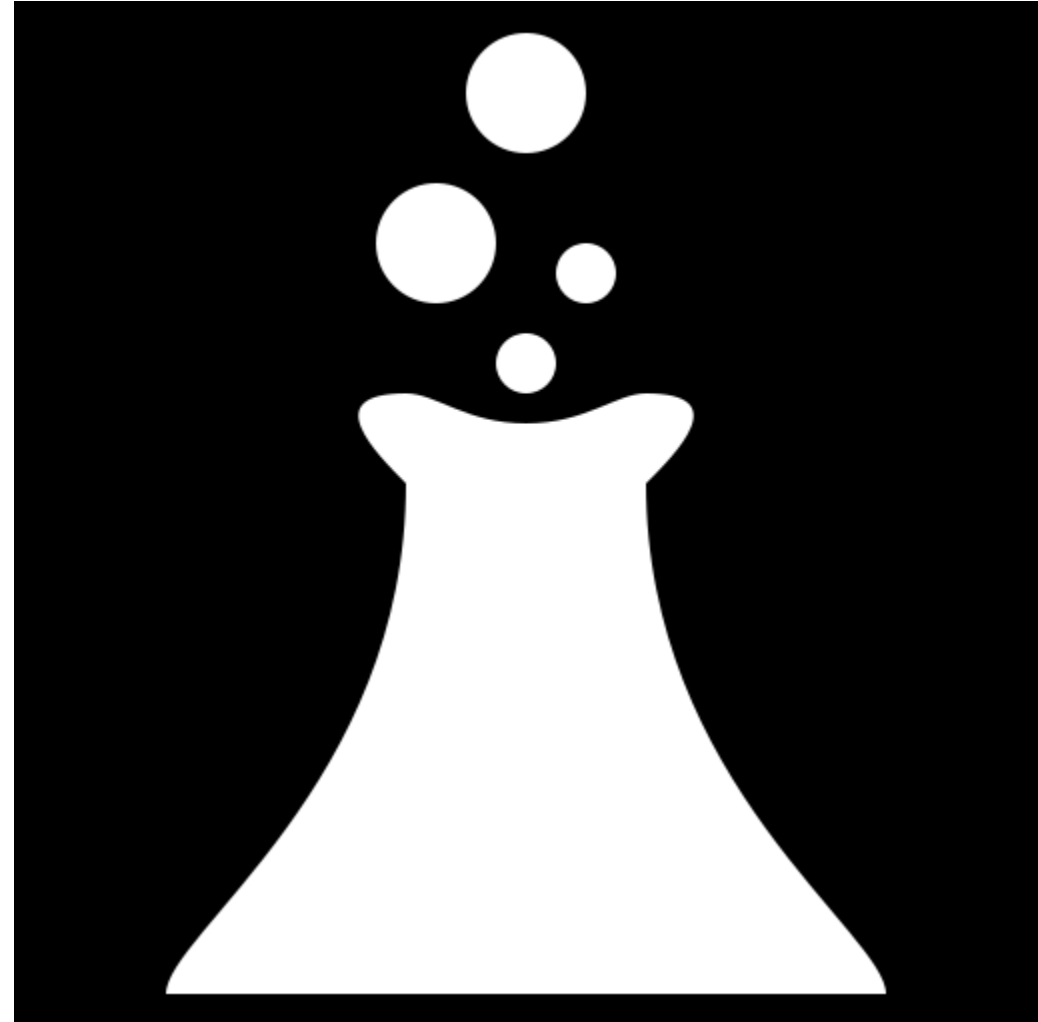
## 2 Types of Defenses

### 1. Physical Barriers of the Body

- a. ~~Skin~~
- b. ~~Mucous Membranes~~

### 2. Chemical Defenses

- a. ~~Sweat~~
- b. Acidic Environments
- c. Lysozyme





# ACIDIC ENVIRONMENTS

- The **acidic environments** of urinary tract, stomach and vagina discourages microbial growth.

# THE FIRST LINE OF DEFENSE - Prevention

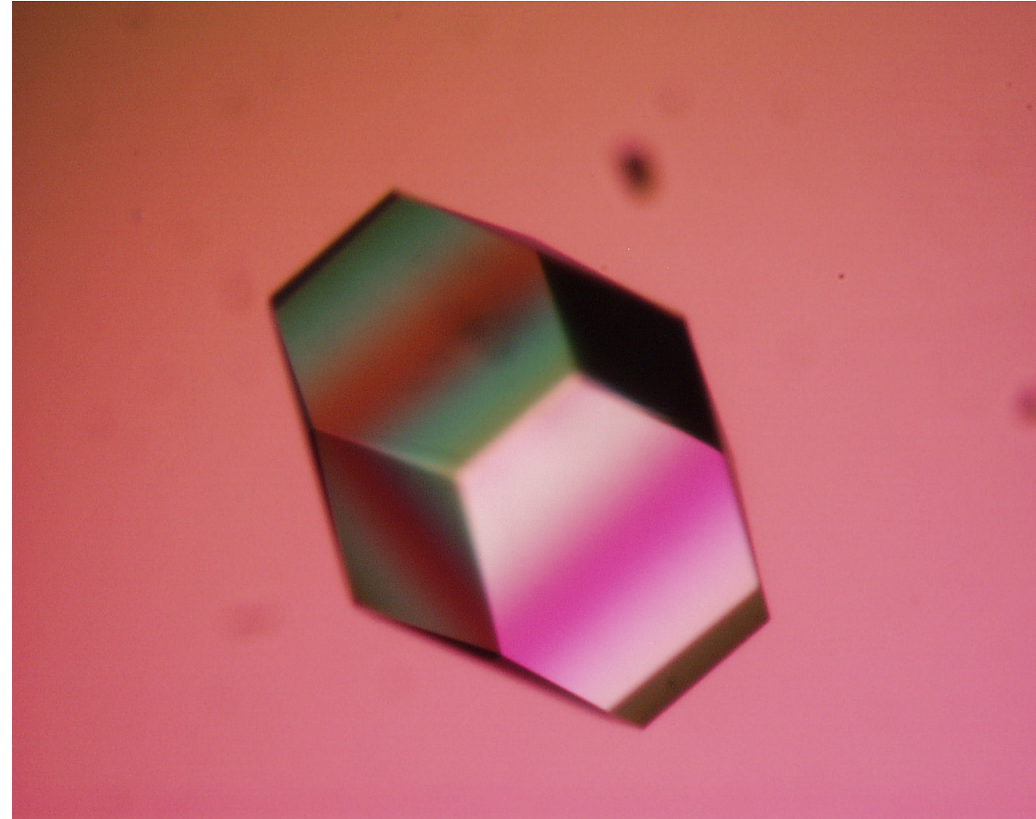
## 2 Types of Defenses

### 1. Physical Barriers of the Body

- a. ~~Skin~~
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### 2. Chemical Defenses

- a. ~~Sweat~~
- b. ~~Acidic Environments~~
- c. Lysozyme




# Lysozyme

---

- Saliva and tears contains an enzyme called **lysozyme** that functions to block the synthesis of the bacterial cell wall.
- When the bacterial cell wall cannot be synthesized or repaired, the bacteria dies soon after.





# Nonspecific Resistance (Innate Immunity)

- The Second Line of  
Defense

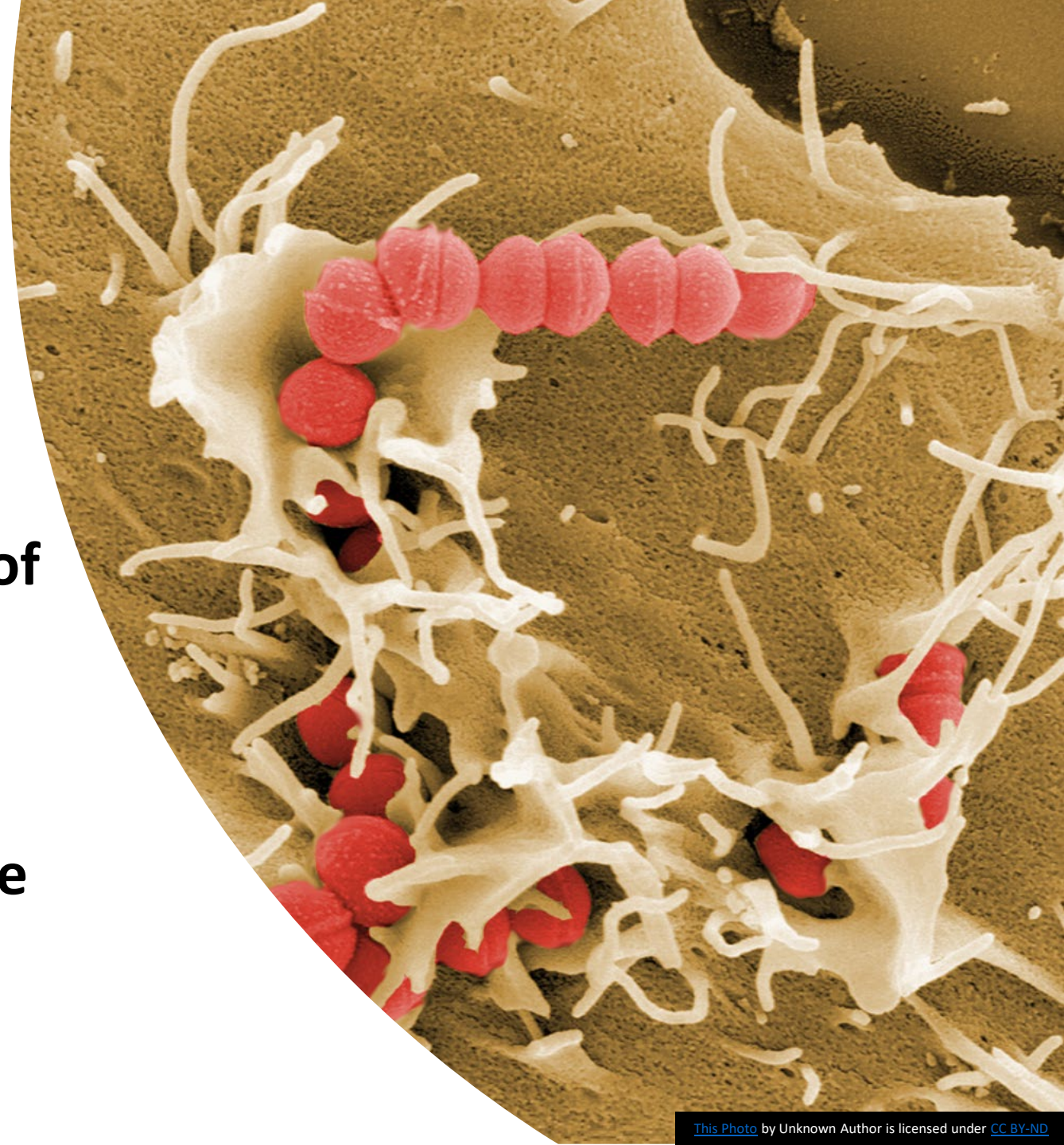




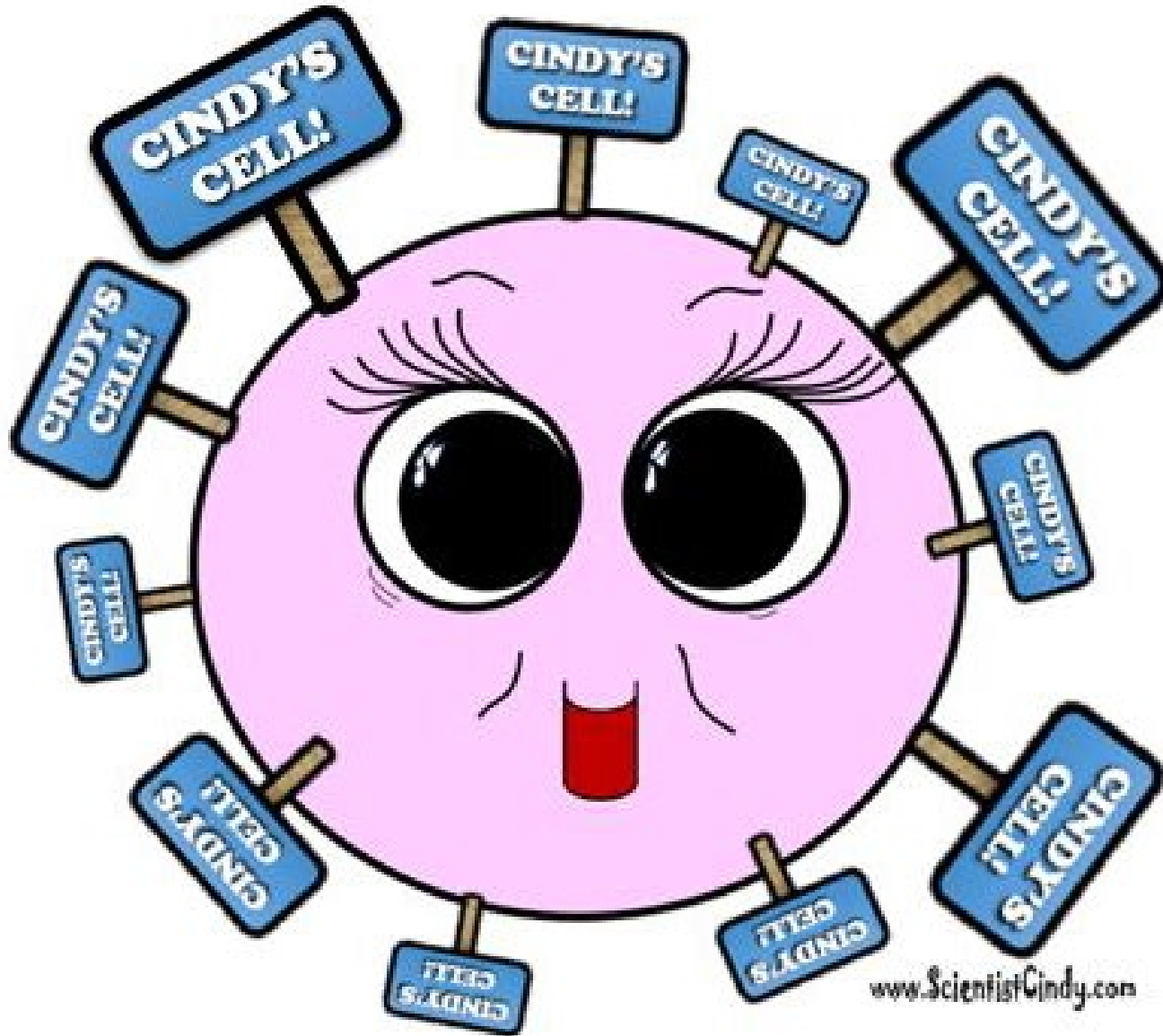
# INVASION!

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- Sometimes the body's physical and chemical barriers are not enough to keep pathogen out of the body.
- When a pathogen or other suspicious substance is found inside our body, the second line of defense goes into action!



# HOW ARE INTRUDERS IDENTIFIED?

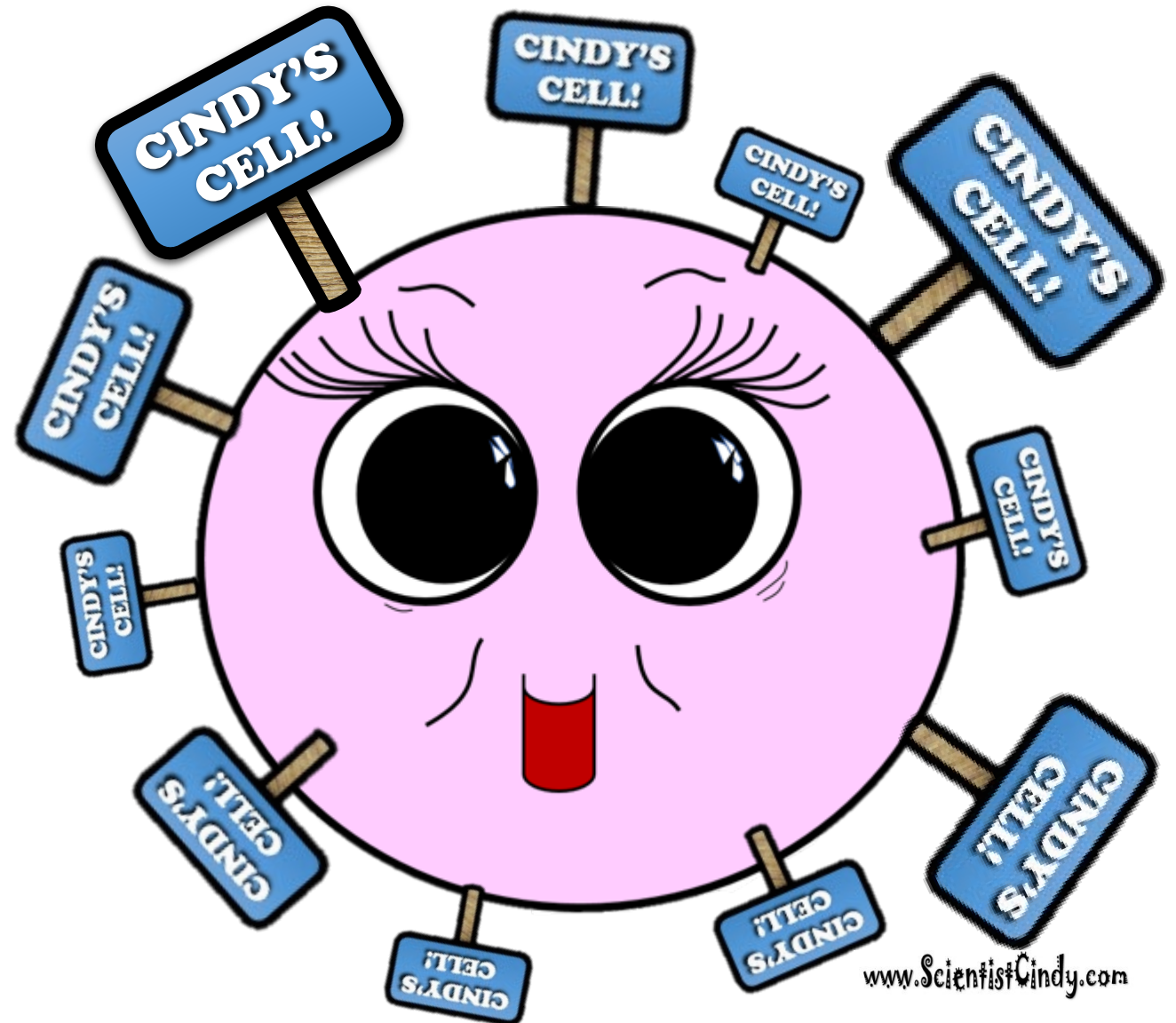


## Step One: Identifying "Self" from "Non-self"

- The cells of each person's body has a unique molecular marker that tells the cells of their immune system that it belongs there and should not be destroyed.

# Major Histocompatibility Complexes (MHC)

- These molecular markers are called **Major Histocompatibility Complexes** (MHC or MHC-I)
- Only identical twins have identical MHCs.



In fact, when a tissue or organ donor is being tested as a possible “match”,

it is the similarity of the MHCs that determines a compatible match!



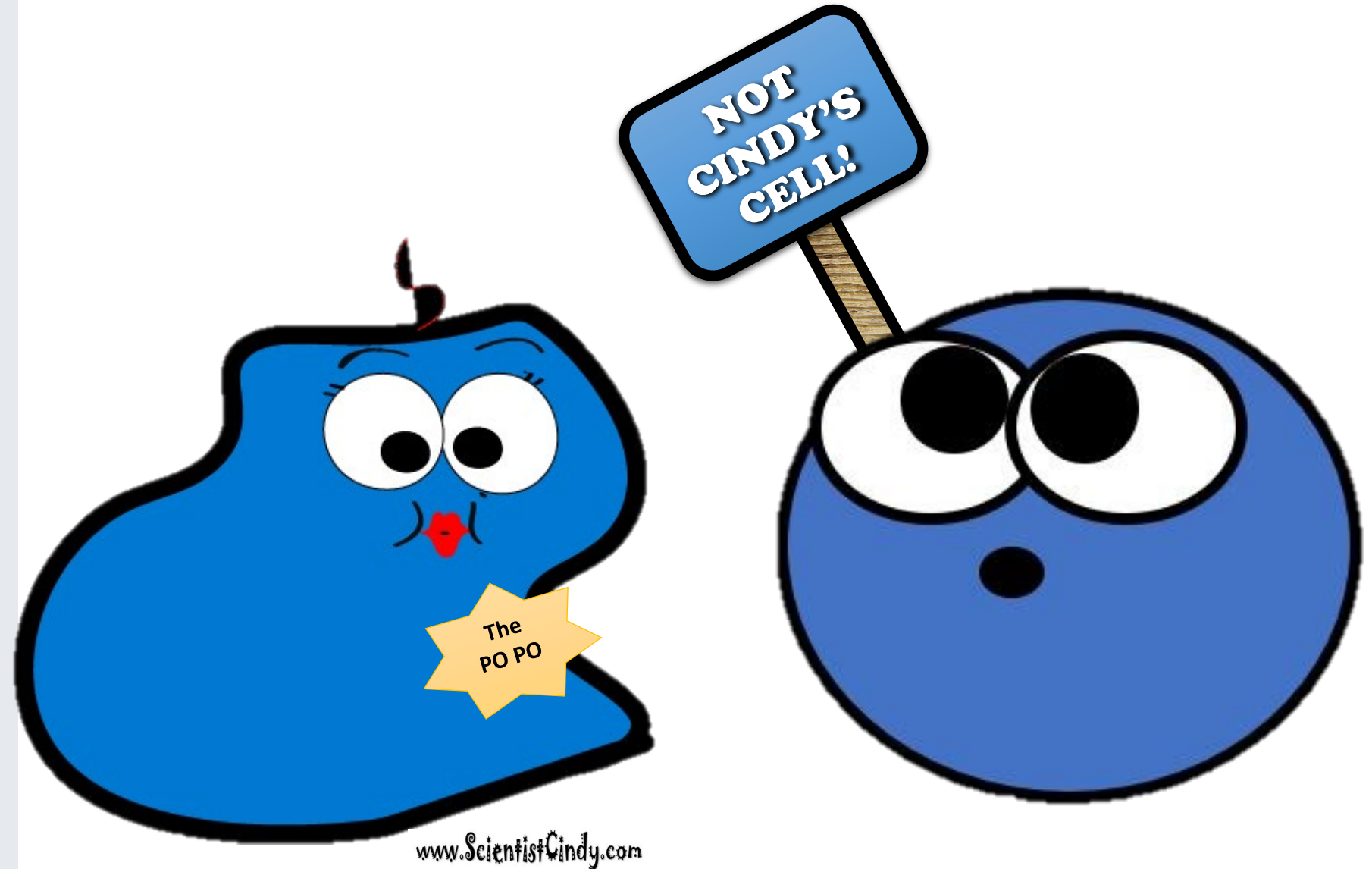
**ORGAN DONATION  
A GIFT FOR LIFE**

# Recognizing Invaders

The immune system is constantly screening the cells of the body and checking these MHC molecules for signs of danger.

Immune cells can use the MHCs to know if a cell is one of the following potential threats

- 1.A Foreign Invader
- 2.A Damaged Cell
- 3.An Infected Cells
- 4.A Mutated or Cancerous Cell



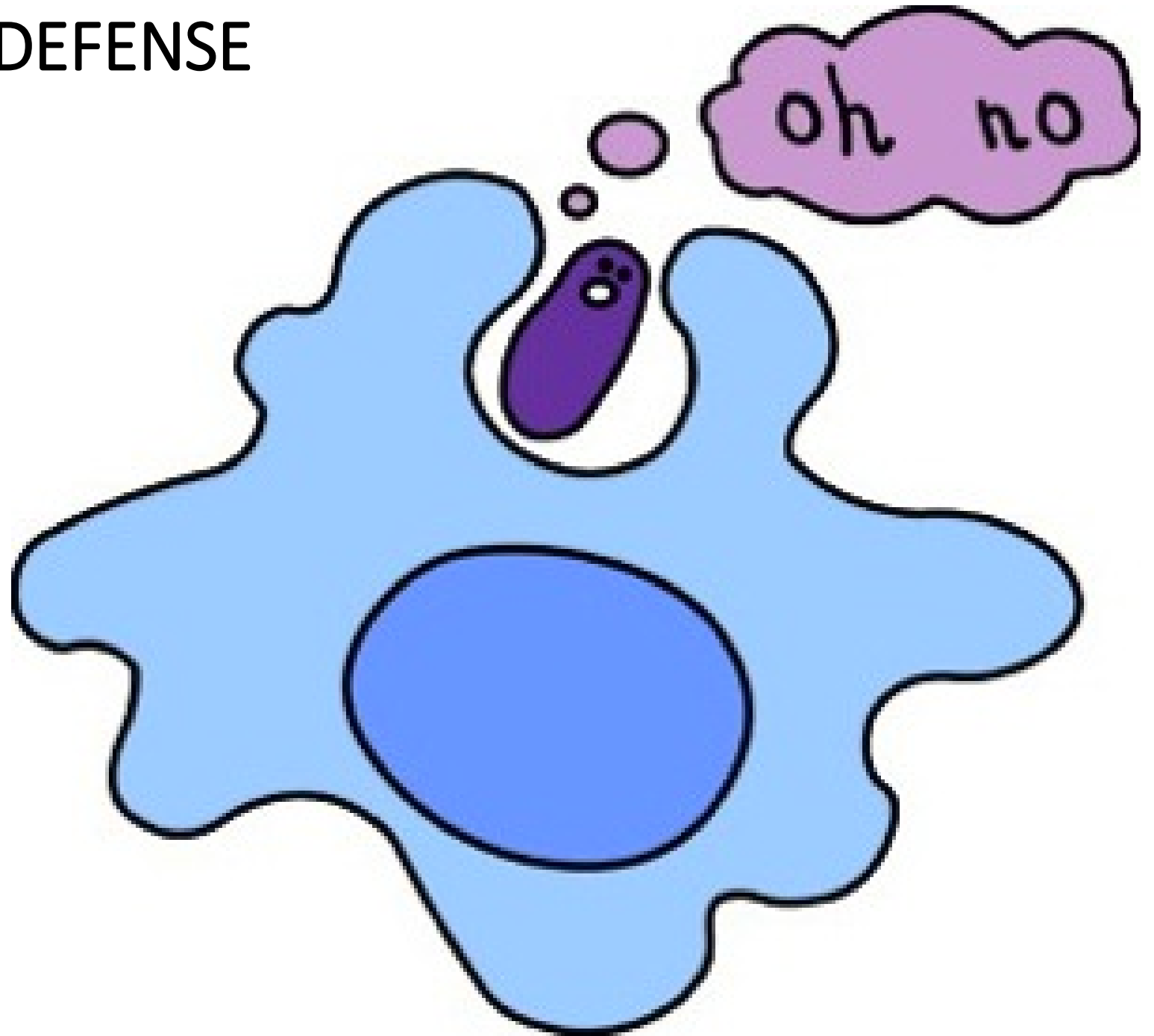
# THE SECOND LINE OF DEFENSE

- **THE SECOND LINE OF DEFENSE**

These defenses are the

1. internal cellular and
2. chemical defenses

of the body that kick into action if the pathogen enters the body.



# *Defensive Strategies of the Second Line of Defense*

<b>Defense</b>	<b>Example</b>	<b>Function of the Defense</b>
Defensive Cells	Phagocytes (Neutrophils and Macrophages)	Engulfs (eats) Foreign Invaders of the Body
	Eosinophils	Kills Parasites
	Natural Killer Cells	Kills Some Invading Organisms
Defensive Proteins	Interferons	Slows the Spread of Viral Copies
	Complement System	Stimulates histamine release, promotes phagocytosis, kills bacteria, increases inflammatory response
Inflammation	Redness, Heat, Swelling, Pain	Increases Blood Flow to the Area, Recruits Defensive Cells to Come to the Area, Promotes Faster Healing
Fever	Significant Increase in Temperature	Slows Bacterial Growth, Speeds Body Defenses

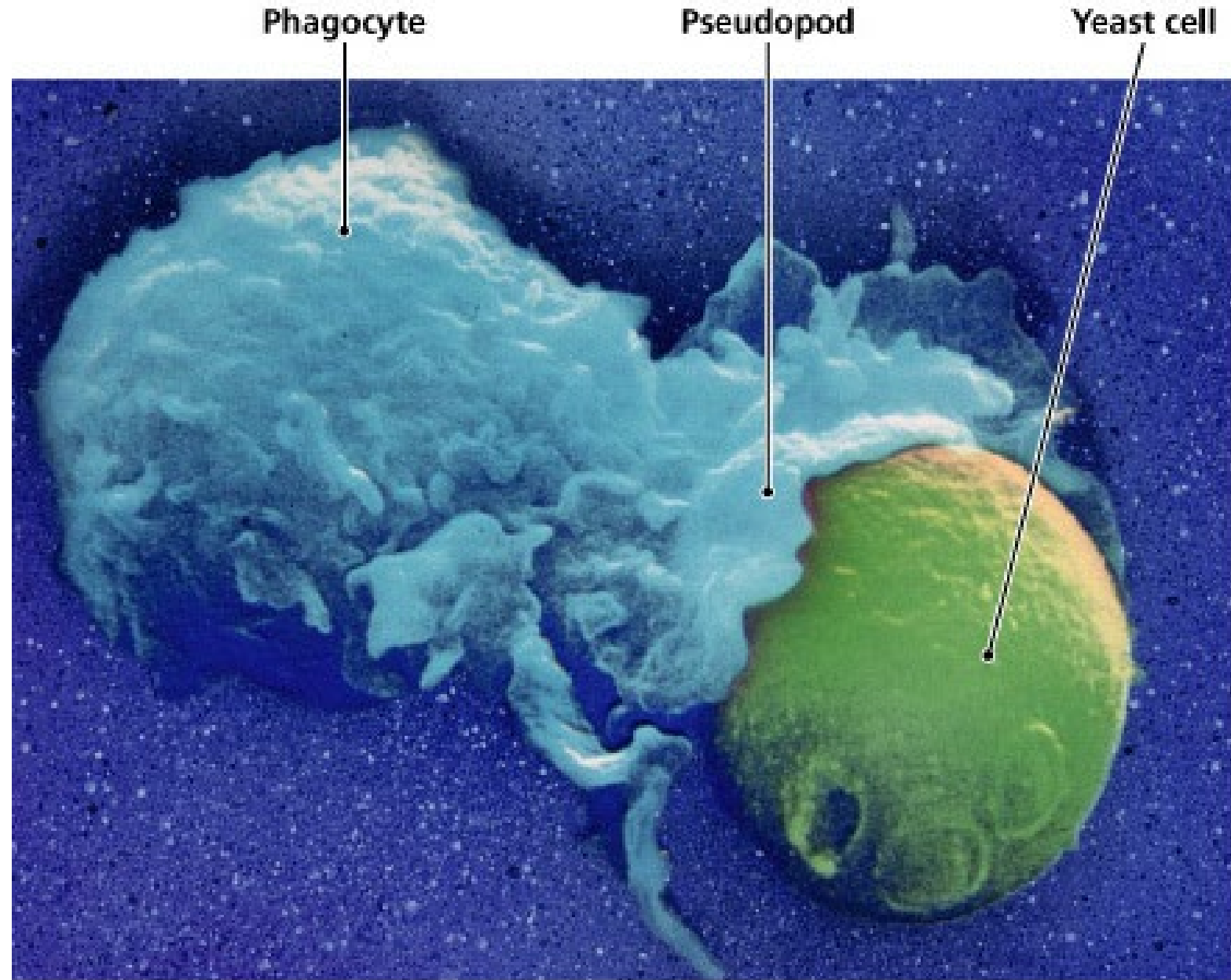
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Fever	Significant Increase in Temperature	Slows Bacterial Growth, Speeds Body Defenses



# PHAGOCYTES

- *Defensive cells* are white blood cells called **phagocytes** that "eat" unwanted invaders of the body, as well as dead or damaged cells.
- The term phagocytes comes from the words for "phage" which means "to eat", and "cyte" which means "cell".
- So phagocytes will "eat" unwanted entities.

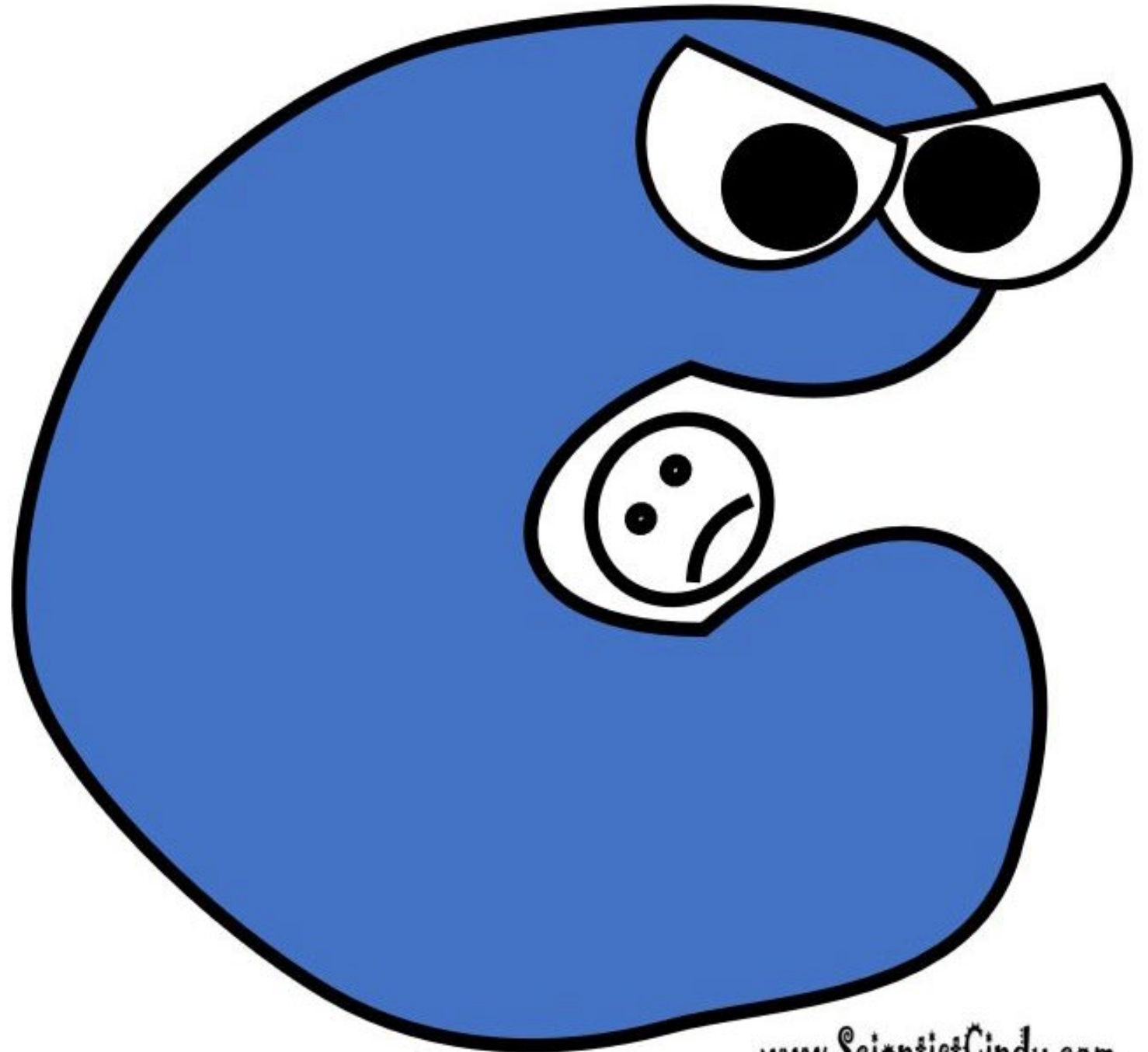


SEM

3 μm

# PHAGOCYTOSIS

- So phagocytes will "eat" unwanted entities found in the body by engulfing them and chemically breaking them down in a process called **phagocytosis**.
- Phagocytes are **nonspecific** and will get rid of pathogenic organisms, as well as dead or damaged cells or unwanted debris found in the body.
- In a sense, they are the body's janitorial service.



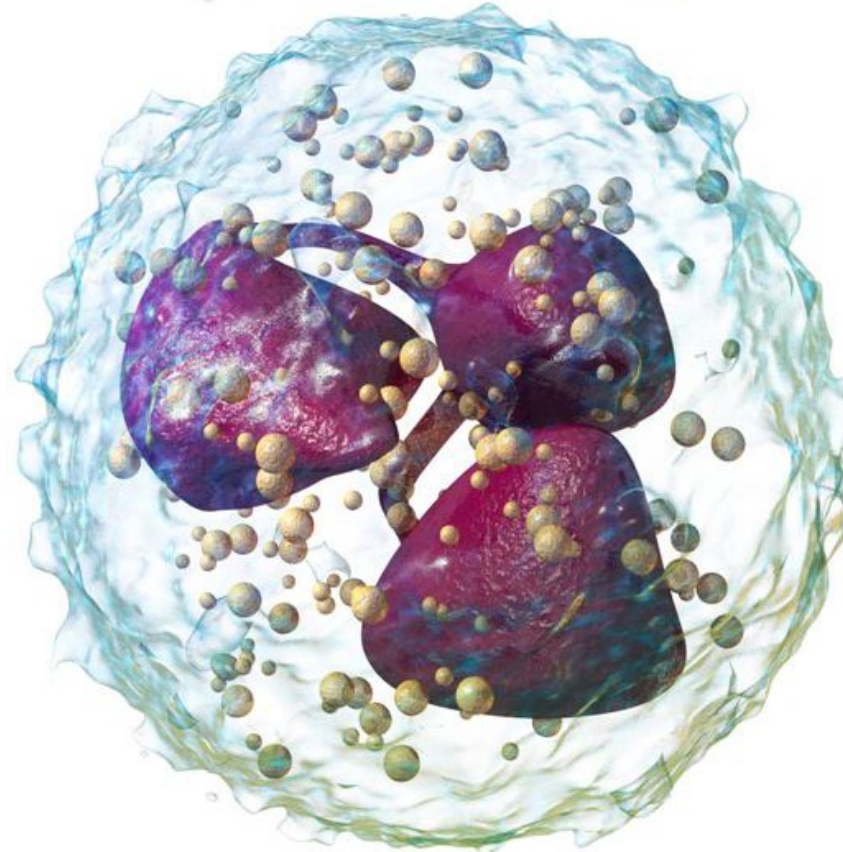
# THE TWO TYPES OF PHAGOCYTES

The human body has two types of phagocytes;

1. Neutrophils
2. Monocytes (Macrophages).

Both of these are types of white blood cells, but they have unique morphology, physiology and different mechanisms of action.

## Neutrophil



## Monocyte

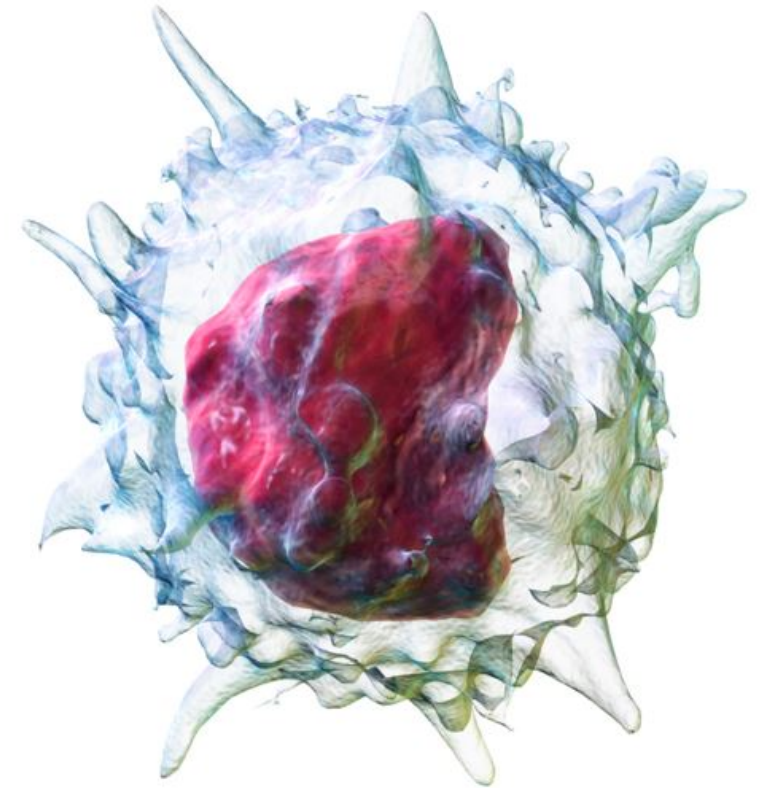


Illustration Courtesy of Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436., CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=56845135>

Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436., CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=56845134>

# *Defensive Strategies of the Second Line of Defense*

Defense	Example	Function of the Defense
Defensive Cells	Phagocytes (Neutrophils and Macrophages)	Engulfs (eats) Foreign Invaders of the Body
	Eosinophils	Kills Parasites
	Natural Killer Cells	Kills Some Invading Organisms
Defensive Proteins	Interferons	Slows the Spread of Viral Copies
	Complement System	Stimulates histamine release, promotes phagocytosis, kills bacteria, increases inflammatory response
Inflammation	Redness, Heat, Swelling, Pain	Increases Blood Flow to the Area, Recruits Defensive Cells to Come to the Area, Promotes Faster Healing
Fever	Significant Increase in Temperature	Slows Bacterial Growth, Speeds Body Defenses

## THE NEUTROPHILS

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**The neutrophils are one of the two types of white blood cells categorized as phagocytes..**

- They are the first responders.**

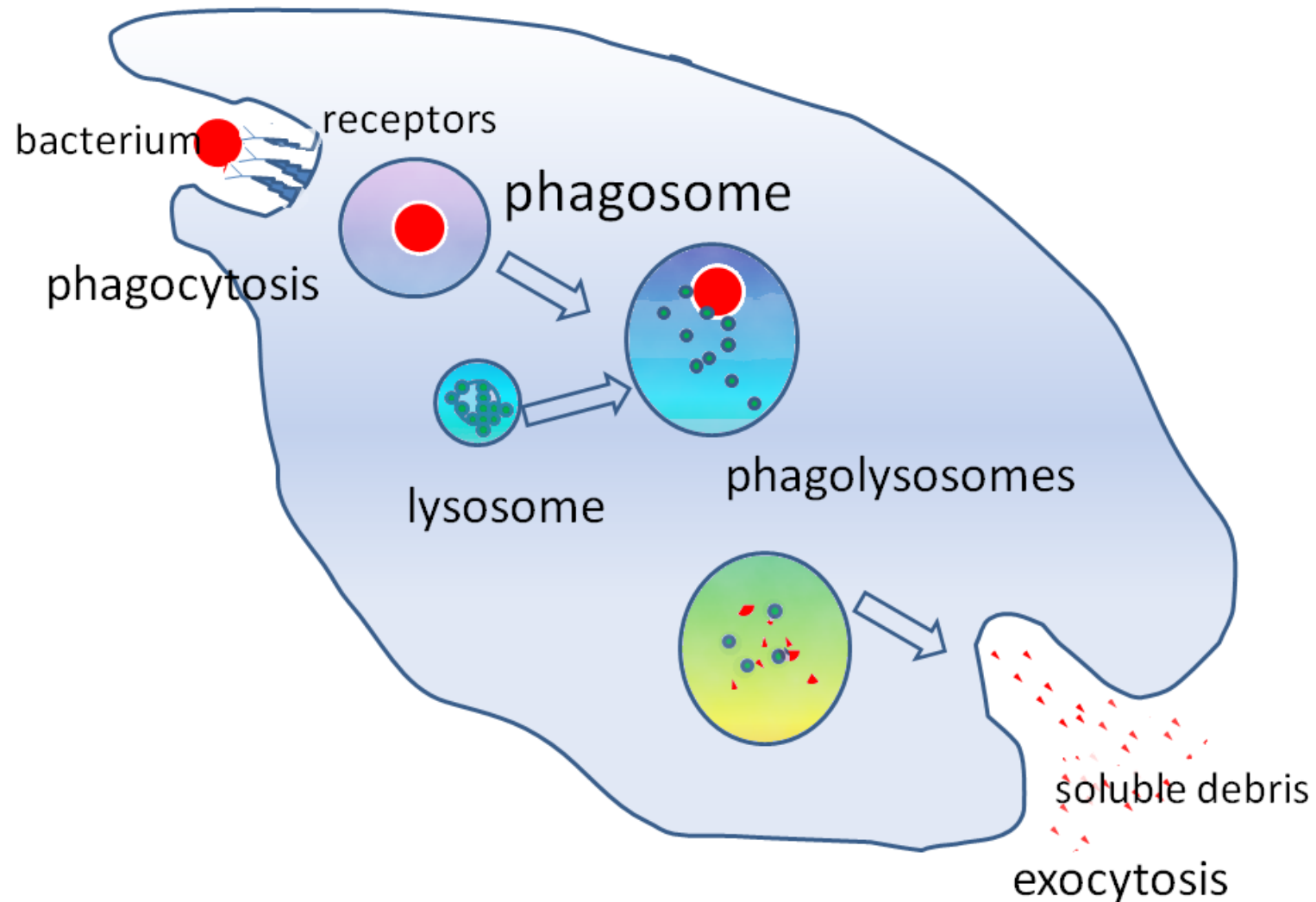
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# Monocytes (macrophages)

Monocytes (macrophages) are the other types of white blood cells that are categorized as phagocytes.

- Live in lymphatic fluids
- They are able to consume large particles of debris
- Can consume large amounts.
- Eats a larger variety of things than neutrophils.



# Monocytes (macrophages)

- A macrophage ingesting a bacterium (the rod-shaped structure).
- The bacterium will be pulled inside the cell within a membrane-bound vesicle and quickly killed. –

<http://schoolbag.info/biology/humans/17.html>



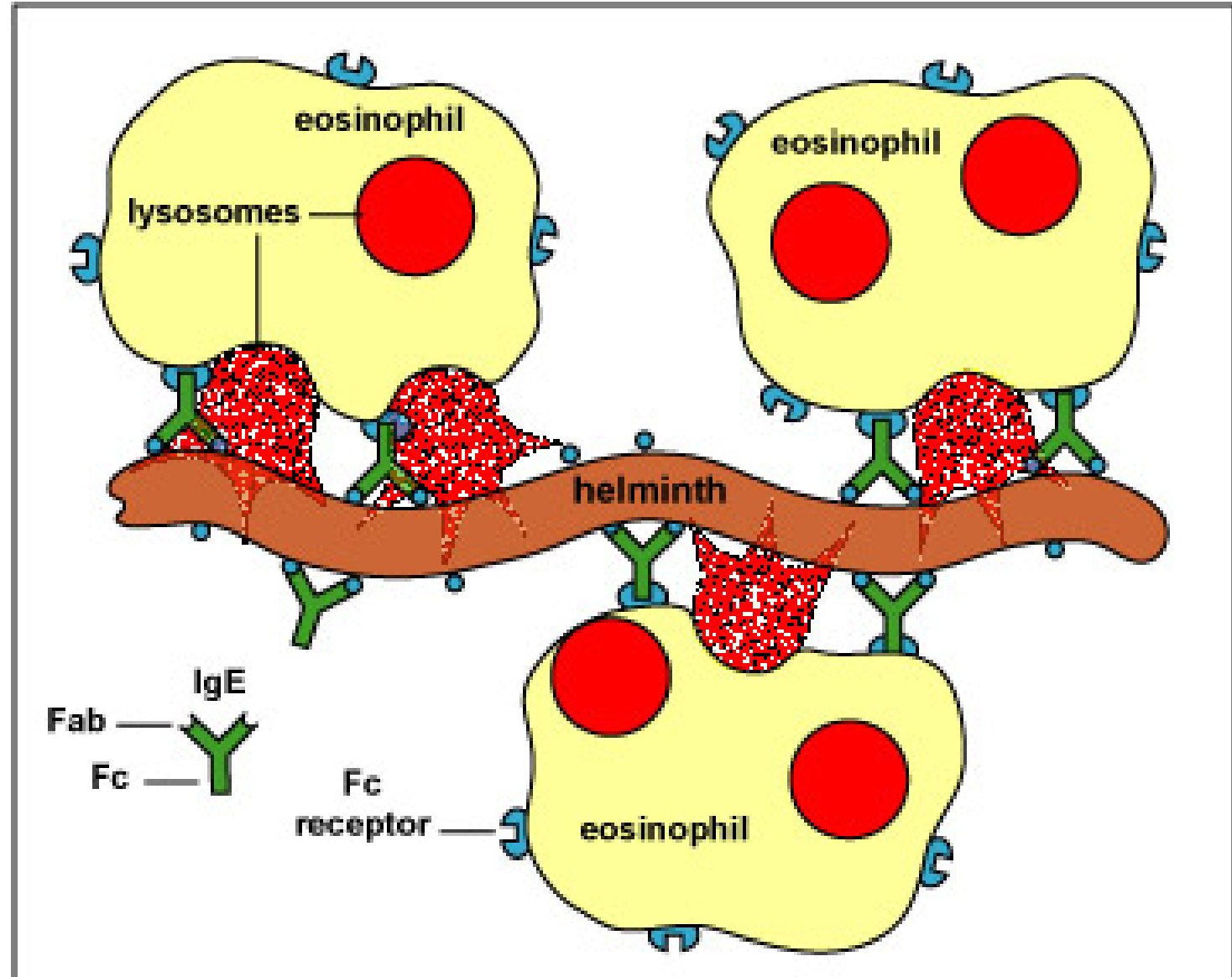


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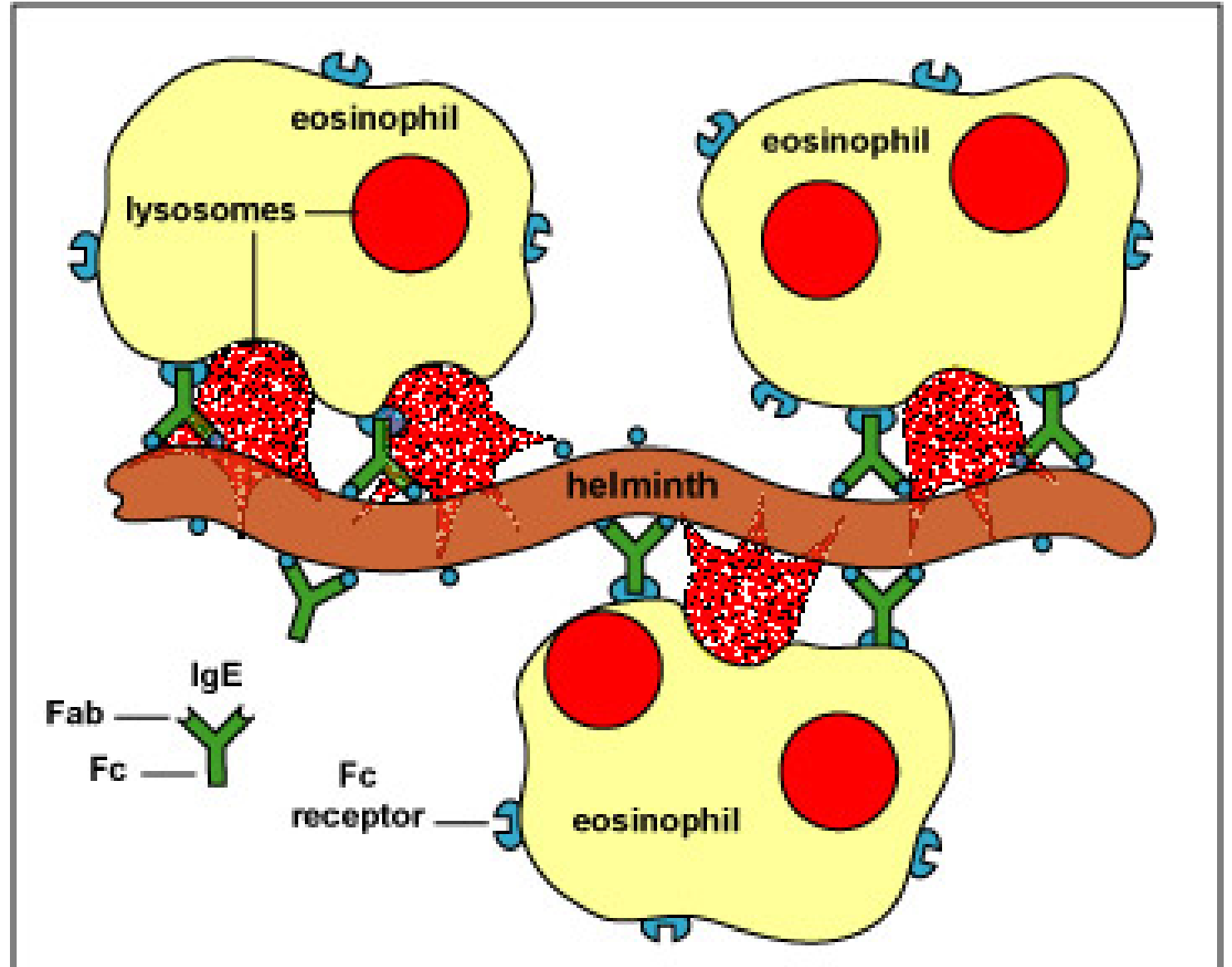
# *EOSINOPHILS*

- The eosinophils specialize in attacking pathogens that are too large for the macrophages to engulf, such as parasitic worms.



# EOSINOPHILS

- Eosinophils function by positioning themselves close to the pathogen and releasing enzymes that kill the organism and break it down into smaller pieces.
- At this point, the macrophages can remove the smaller pieces using phagocytosis.

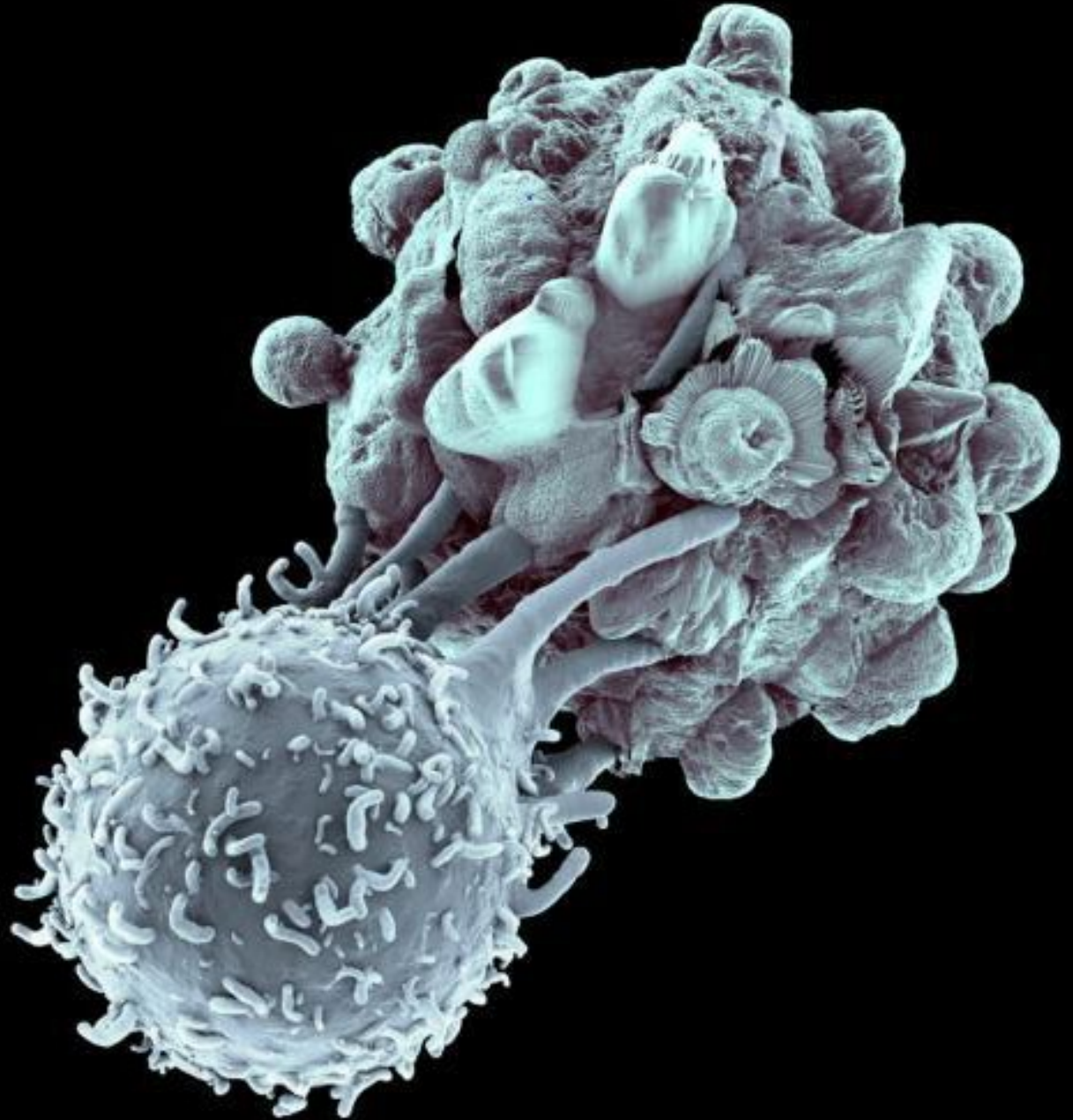


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# Natural Killer Cells

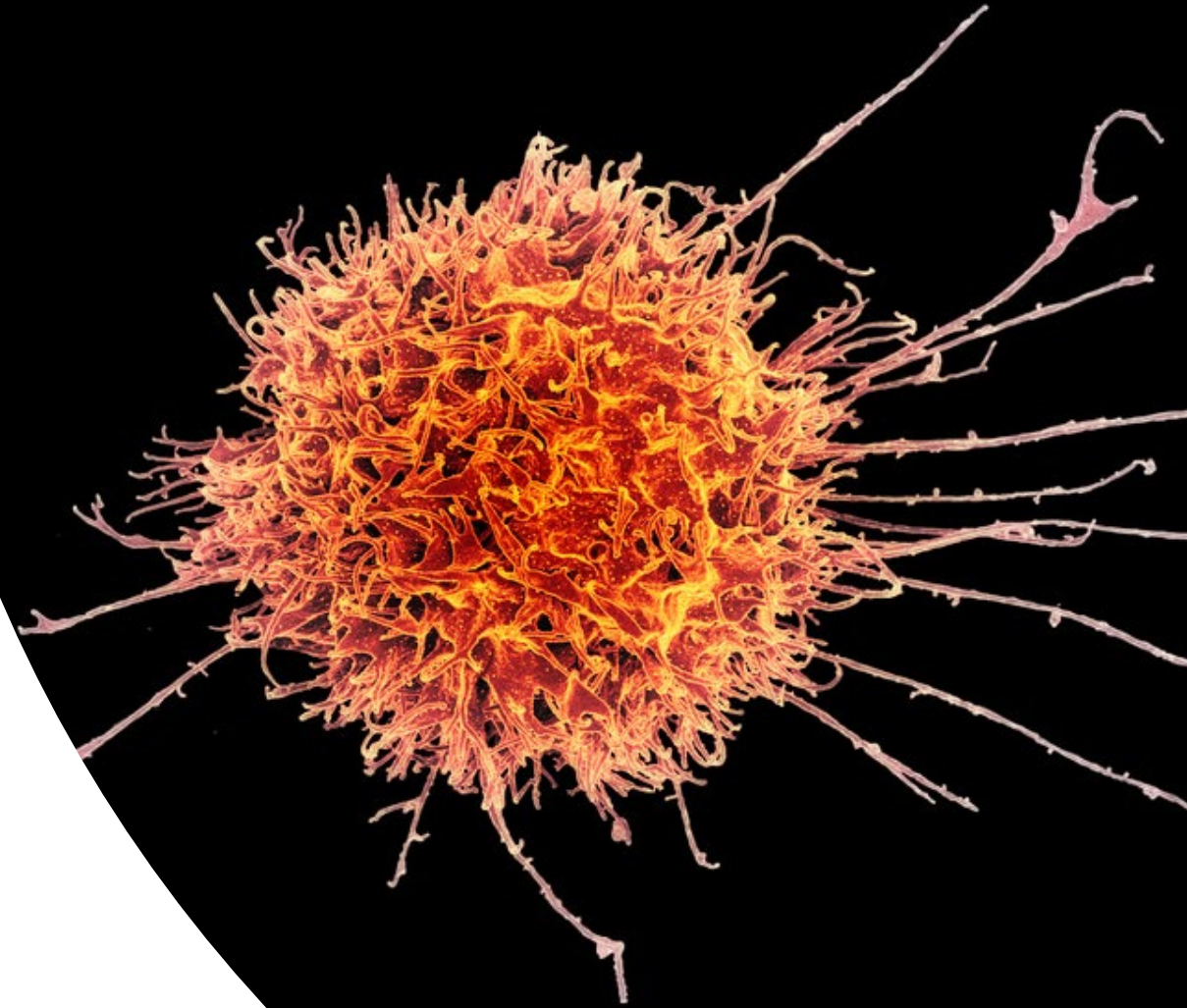
- NATURAL KILLER CELLS induce APOPTOSIS OR KILL virus-infected or tumor cells.
- Natural killer cells function in cell-mediated, cytotoxic innate immunity



# Natural killer cells

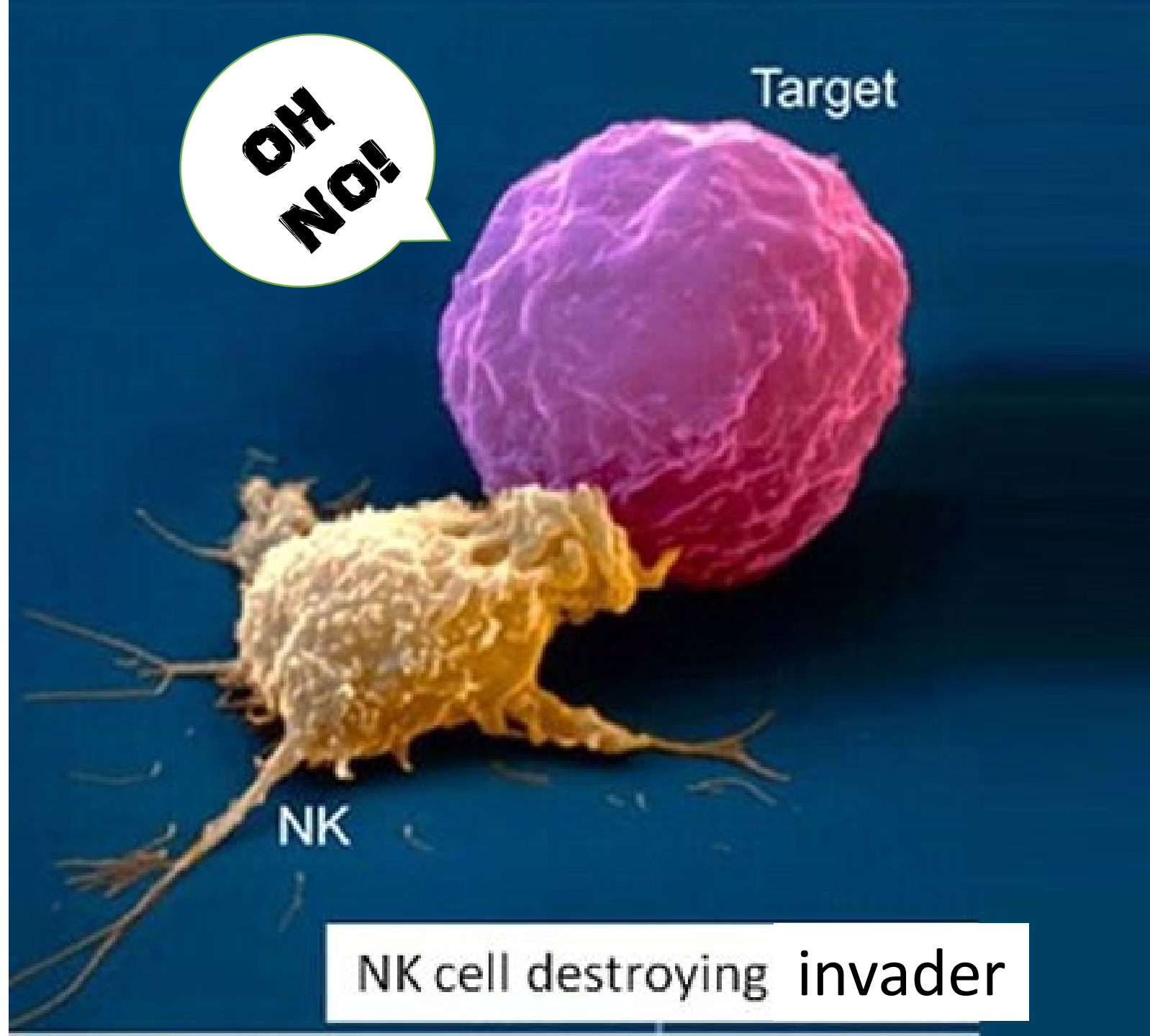
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- **Natural killer cells are constantly on patrol seeking out any suspicious characters it finds in the body.**
- **Natural killer cells (NK cells) will indiscriminately kill anything that it perceives as "abnormal".**
- **This means that the NK cells will not only destroy foreign invaders, but will also destroy the body's own cells that may show signs of mutation, or infection or disease.**



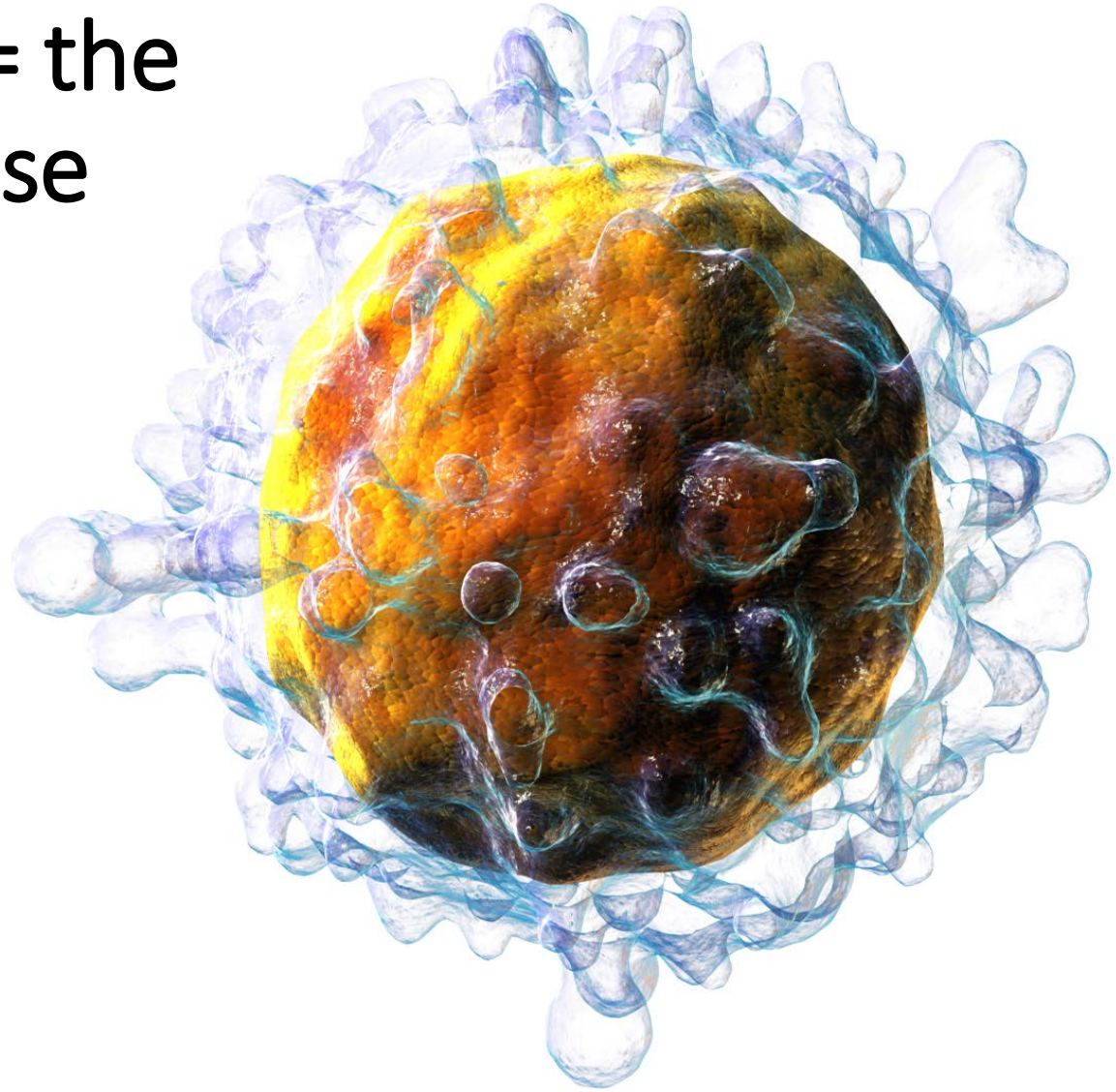
# ***Natural Killer Cells are Indiscriminate Killers***

- For example, host cells that have become cancerous or that have become infected with a virus are likely targets for the NK cells.
- The natural killer cells destroy their target by coming into direct contact with the suspicious cell and secreting proteins that degrade the structural integrity of its membrane until the cell dies.



# THE THIRD OF DEFENSE = the adaptive immune response

- **THE THIRD LINE OF DEFENSE - Destroy -** Destroy the invading pathogen.
- This is the **third line of defense** and it is accomplished as the **adaptive immune response**.



**Lymphocyte**



# Innate (Nonspecific) Immune System

- Includes the **First and Second** lines of defense
- Also called **non-specific** immune responses - Attacks only based on the identification of general threats
- **Innate** (born with it)
- Responds **more quickly** to infection and injury
- **Ready** to fight at all times

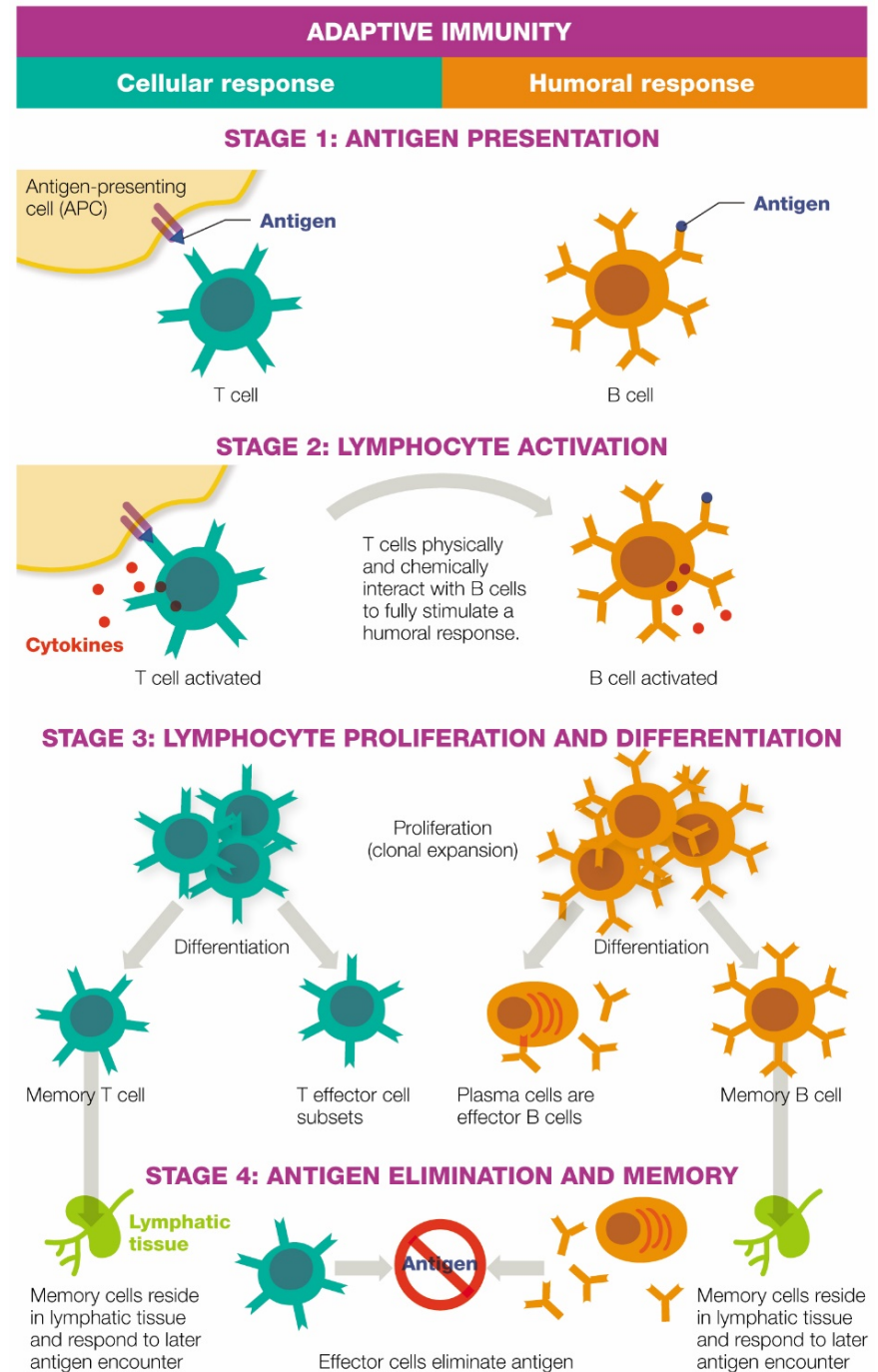
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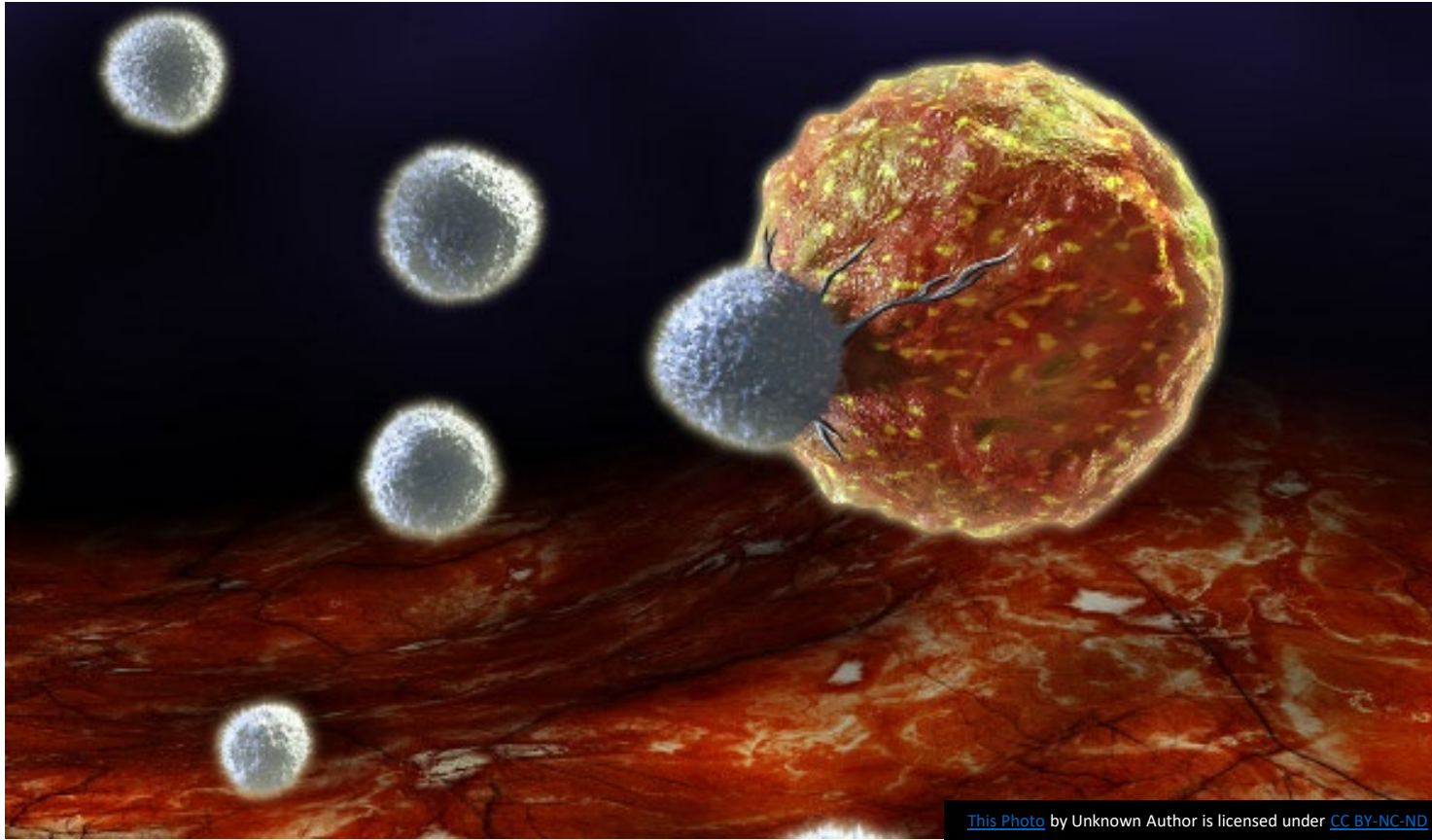
# Adaptive (Specific) Immune System

- Includes the **Third** line of defense only
- Uses **specific** antigens to strategically launch an immune response.
- **Acquired** after birth (from exposure to pathogens)
- **Much slower** to respond to threats and infections
- Is **NOT ready** to fight at all times. Becomes activated only after there has been an exposure to pathogens

*Uses an immunological memory to learn about the threat and enhance the immune response accordingly.*

# Innate Immunity in a Nutshell



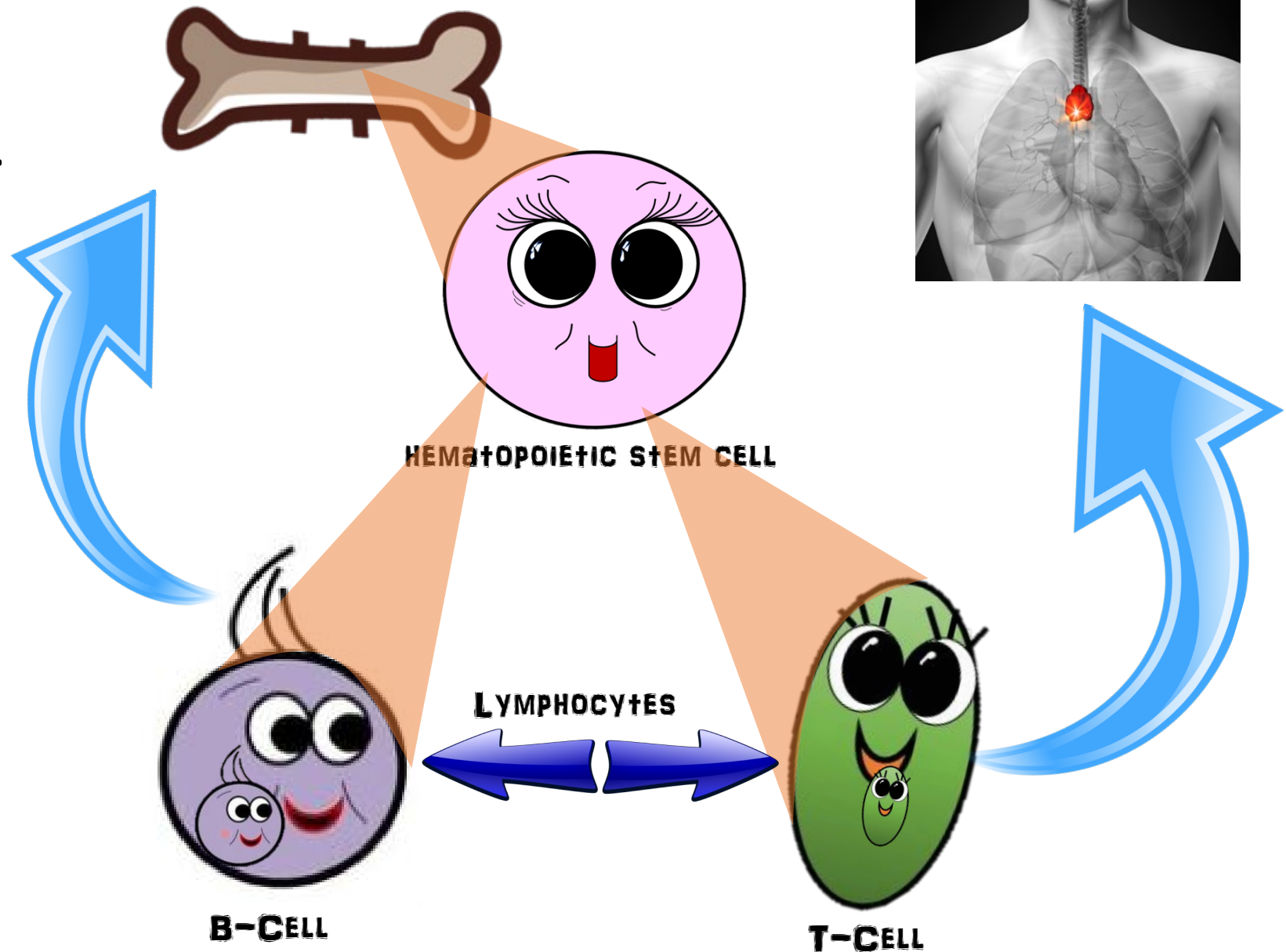


The adaptive immune response involves...

- *B cells and T cells*
- *Recognizing Antigens and Producing Antibodies*

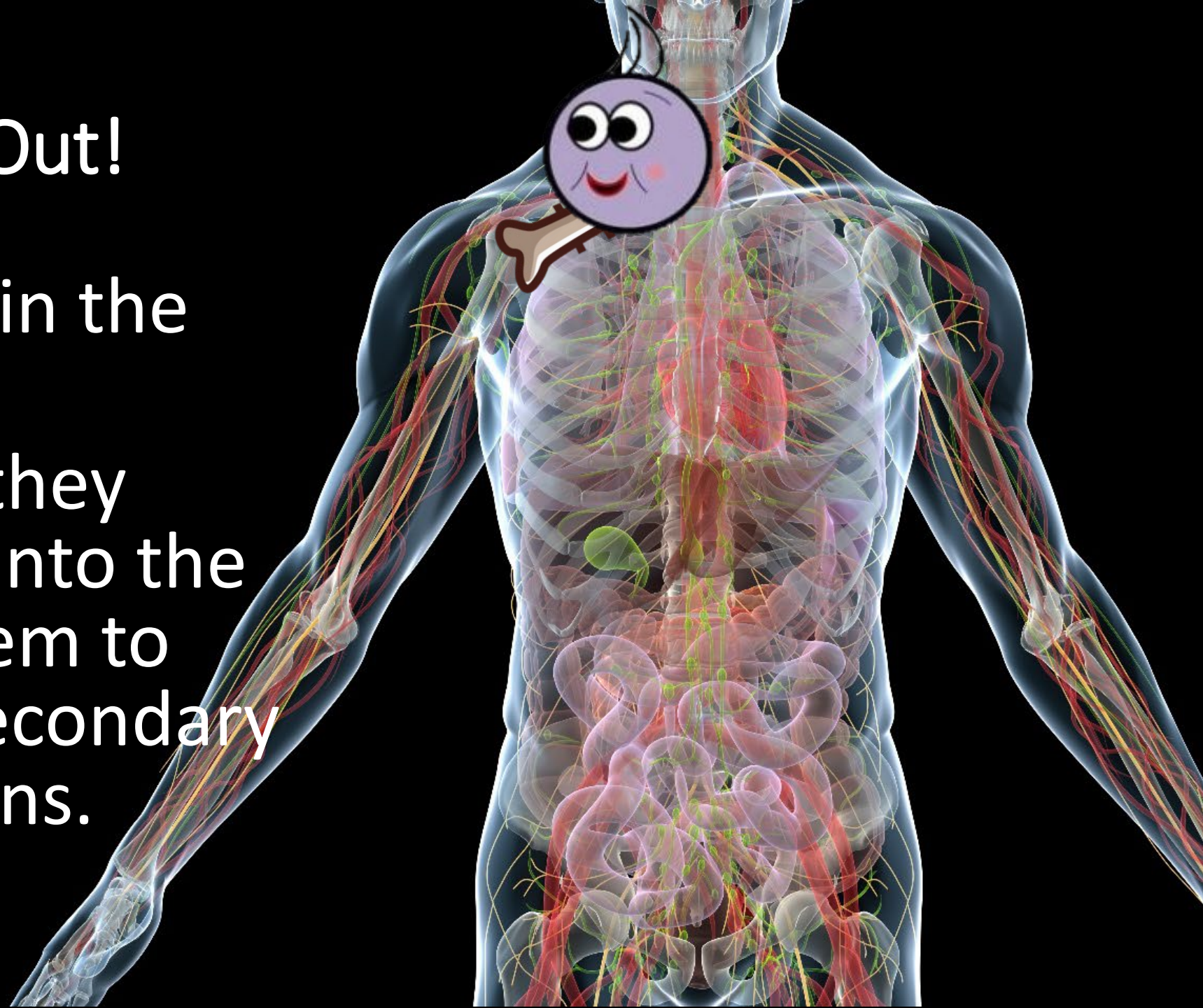
# The cells of the adaptive immune system

- Both B cells and T cells are lymphocytes.
- B-cells and T-cells are derived from hematopoietic stem cells, in red bone marrow.
- B-CELLS MATURE IN THE BONE MARROW
- T-CELLS MATURE IN THE THYMUS GLAND



# B-Cells Moving Out!

- *B-cells* mature in the bone marrow.
- Once mature, they move out and into the lymphatic system to reside in the secondary lymphatic organs.



# Secondary Lymphatic Organs

The B-Cells Stay in  
the Secondary  
Lymphatic Organs  
and Wait to be  
**Activated by the  
presence of an  
ANTIGEN**

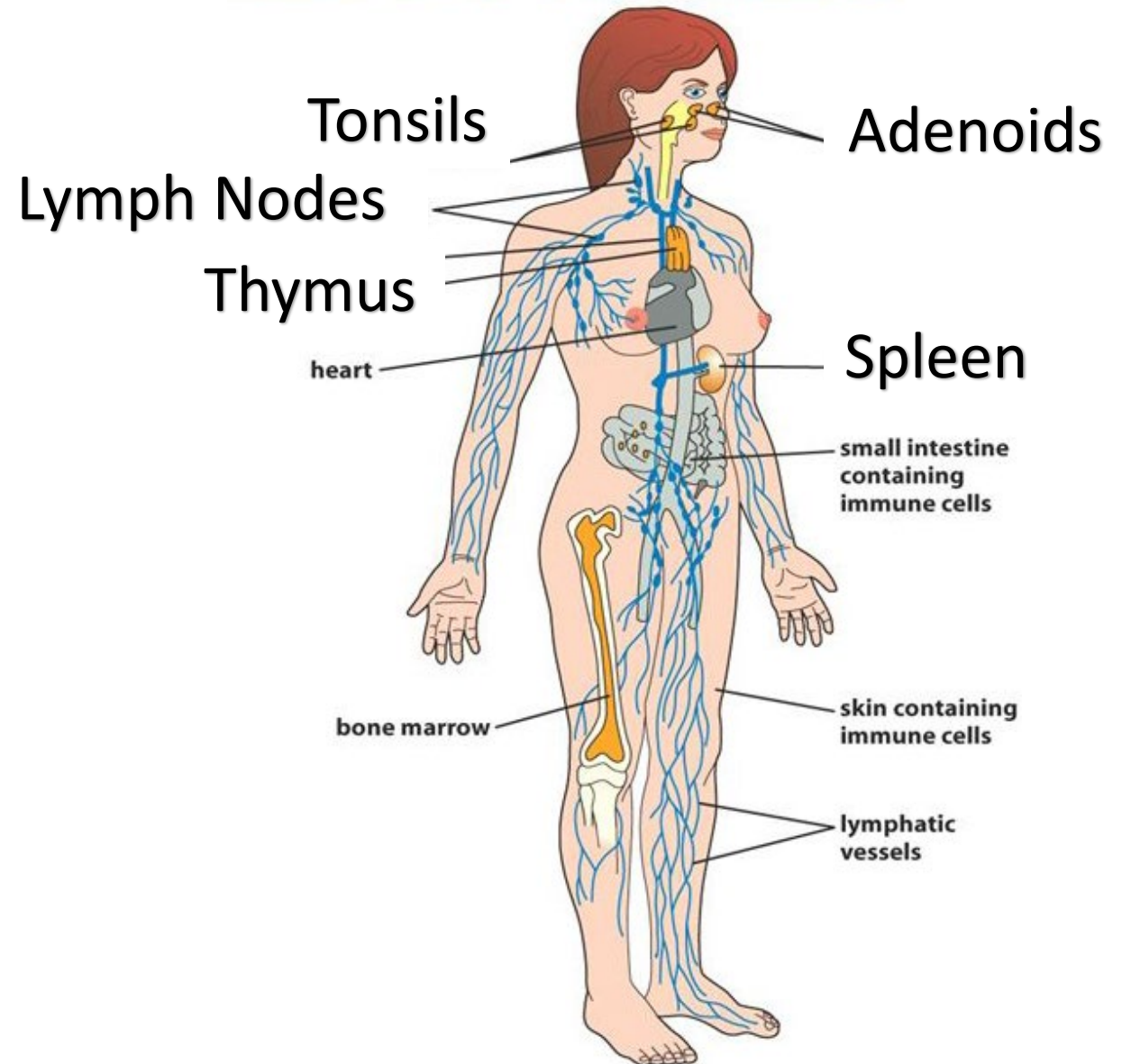
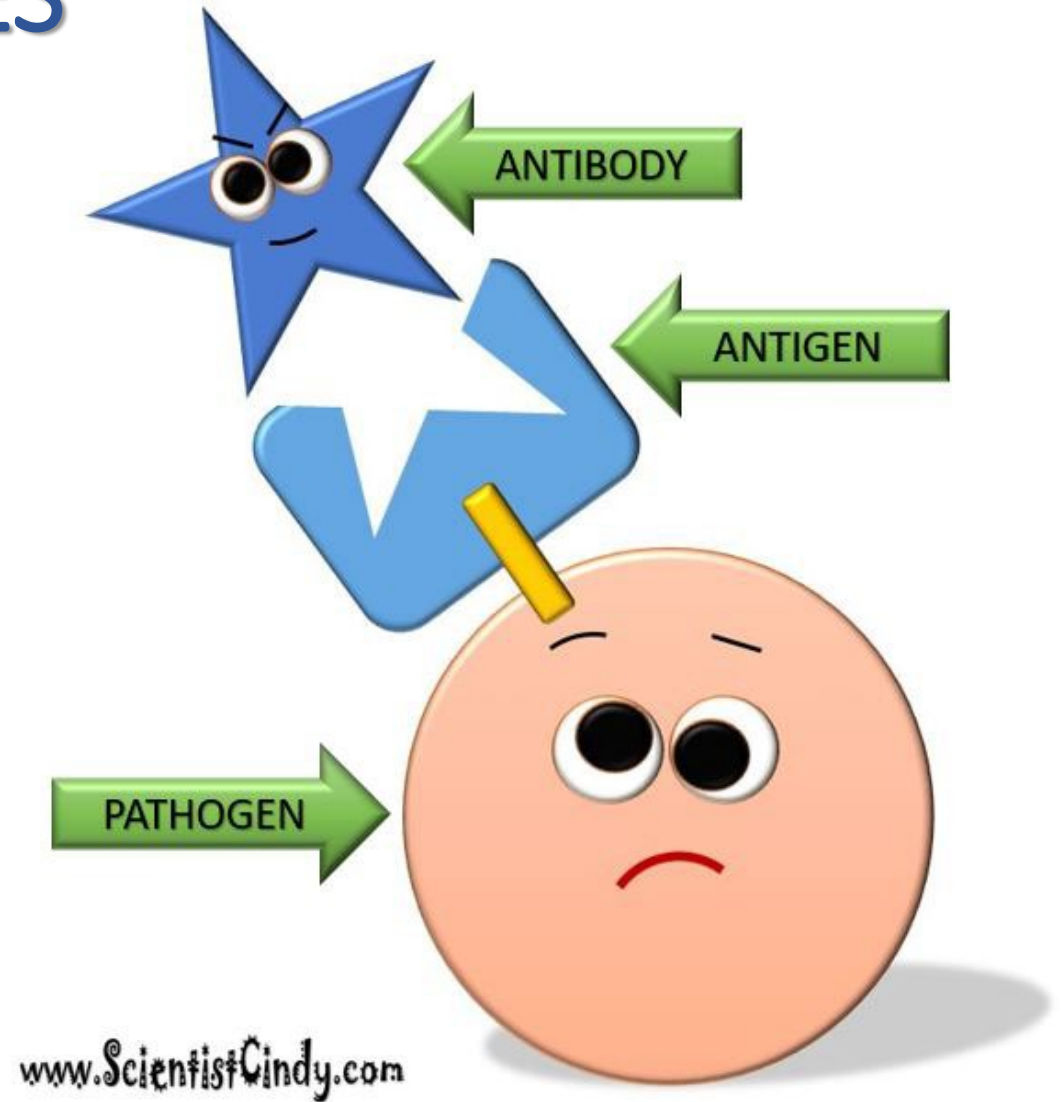


Figure 15-2 Biology Today, 3/e (© 2004 Garland Science)

# ANTIGENS and ANTIBODIES

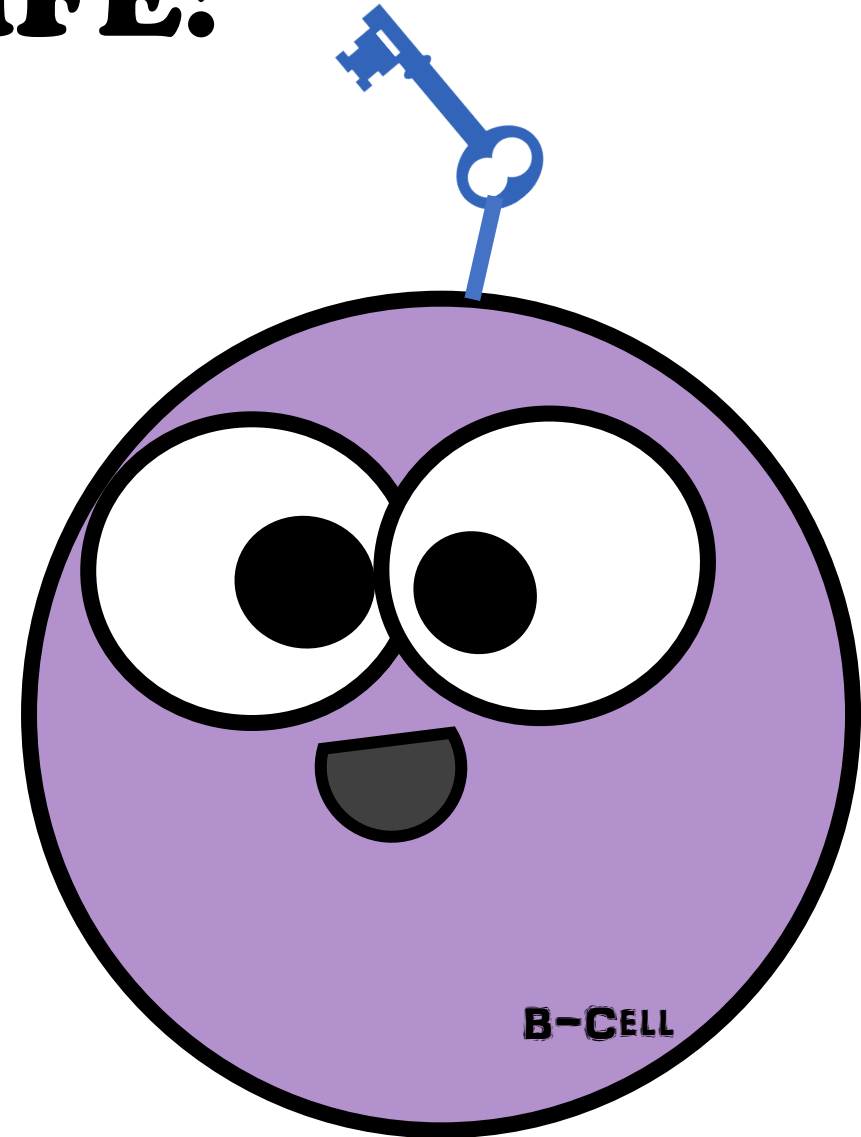
- **ANTIGENS** are defined as anything that has the ability to provoke an immune response
  - Antigens can be viruses, bacteria, or other molecules.
- **ANTIBODIES** (immunoglobulins) are the proteins produced by the immune system to specifically bind to specific antigens.



# **B-Cells PURPOSE IN LIFE!**

The whole purpose in a B-cell's life is to...

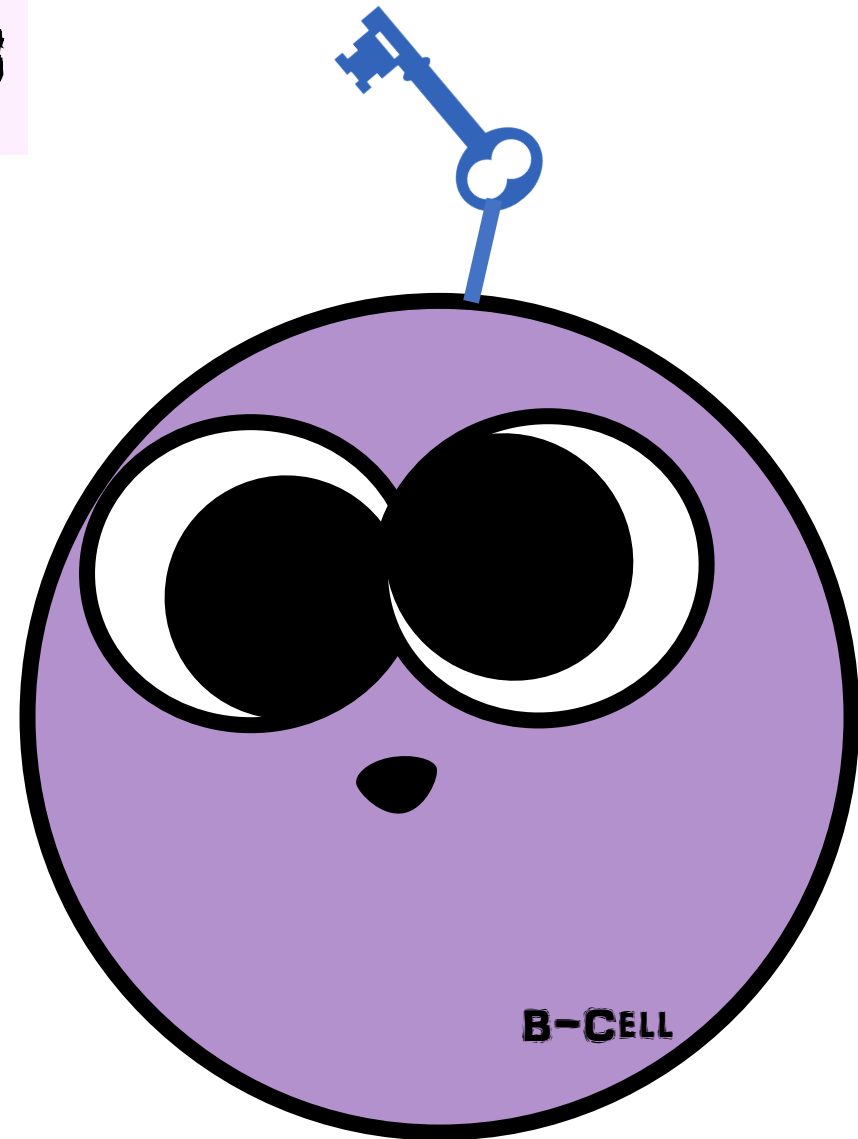
- 1. IDENTIFY ANTIGENS**
- 2. ALERT THE IMMUNE SYSTEM THAT AN ANTIGEN HAS BEEN FOUND**
- 3. SECRETE ANTIBODIES**



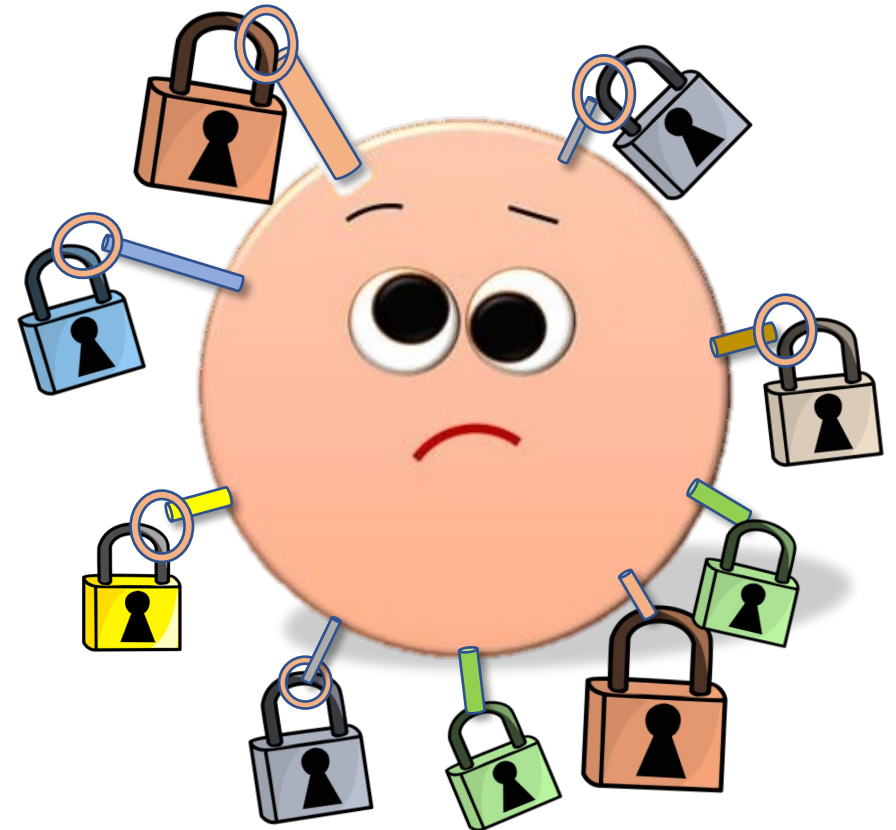
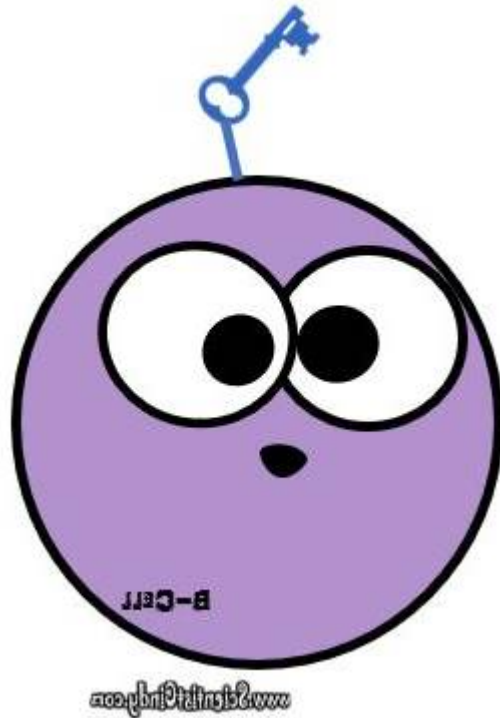


# B-CELLS HAVE ANTIBODIES

- B-Cells produce antibodies (or immunoglobulins) that they place on their cell's surface.
- The membrane-bound antibodies act like **KEYS** and are able to bind to an antigen, because they fit with it, kind of like as if it were a **LOCK**.



- Each B-Cells contains antibodies (like a key) that are specific to only one antigen.
- A pathogen can have many antigens, but the B-Cell has only key to one antigen.

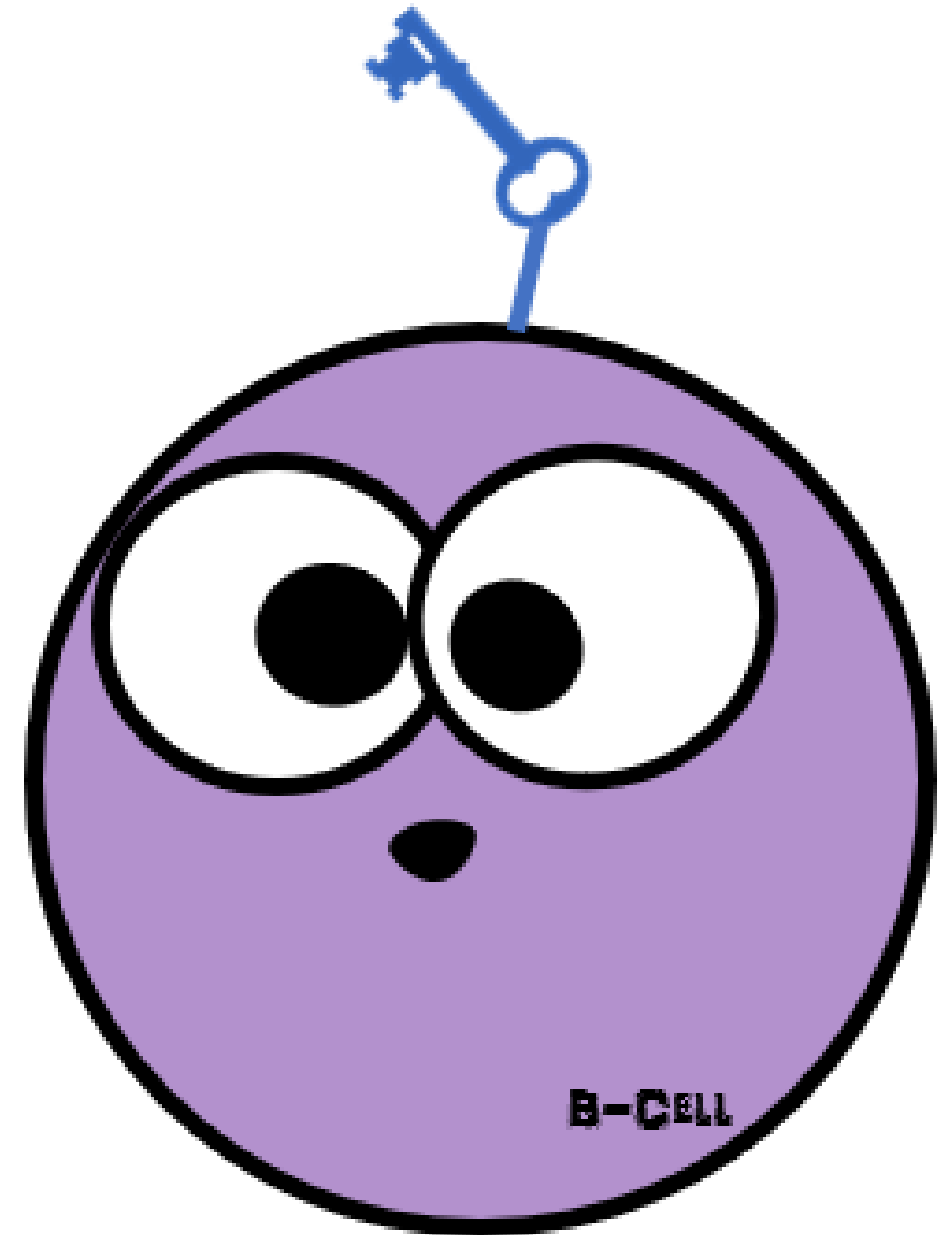
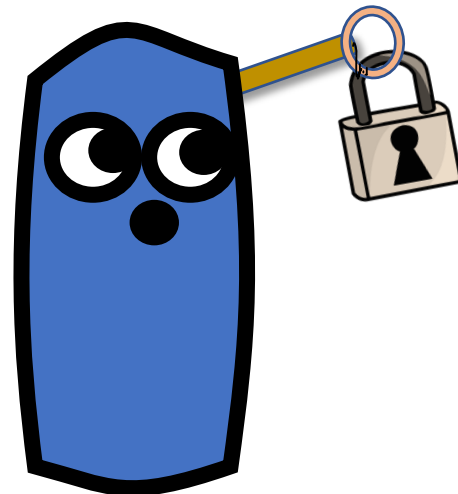


**B-CELL CARRYING ANTIBODIES meets a PATHOGEN with ANTIGENS**

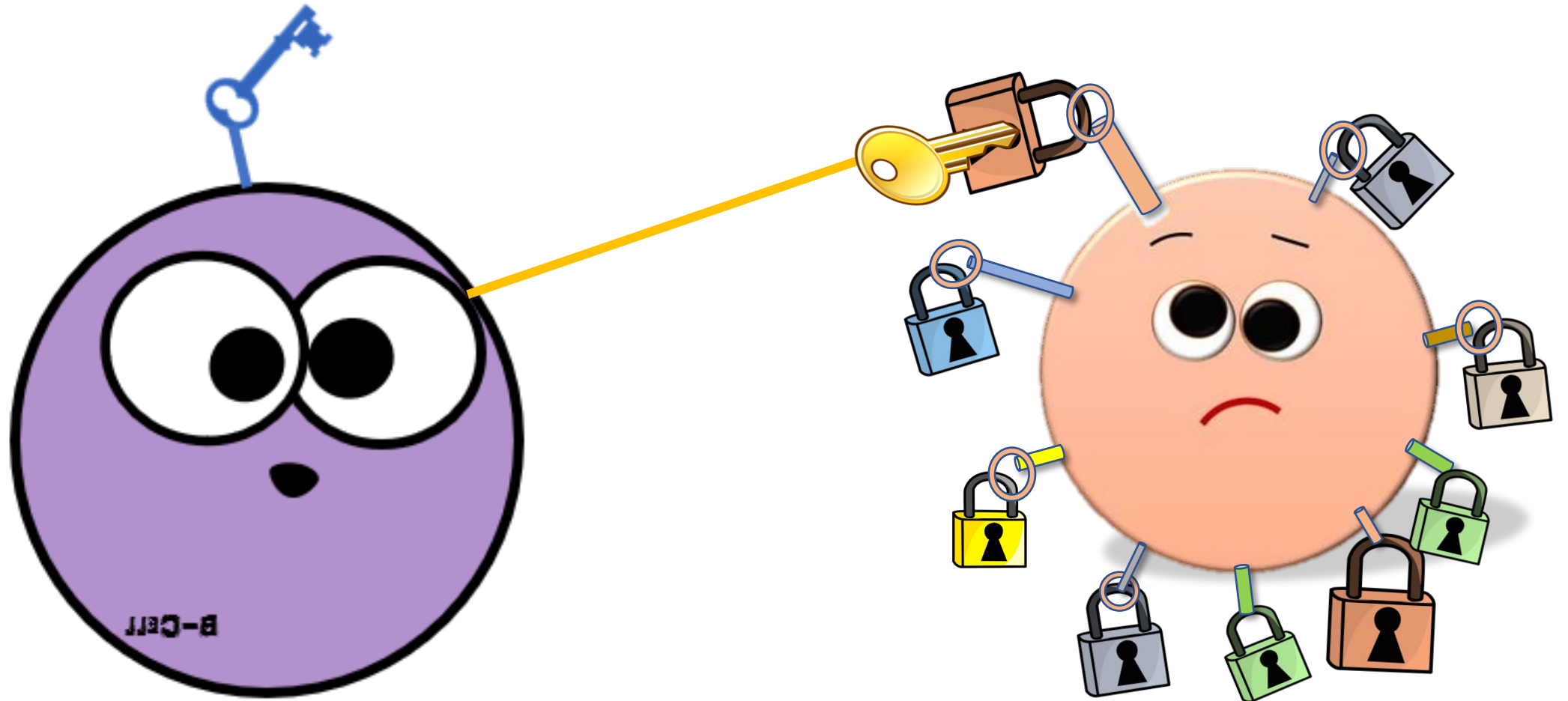
# ***THE INVASION!***

- When an antigen invades the body, it will encounter many B-Cells.
- Since, each B-Cell is specific to only one antigen, the antigen may come across a multitude of B-Cells that it does not bind with... before it comes across a B-Cell that DOES!

Oh! Umm.. I was.. Umm.. just passing through officer.

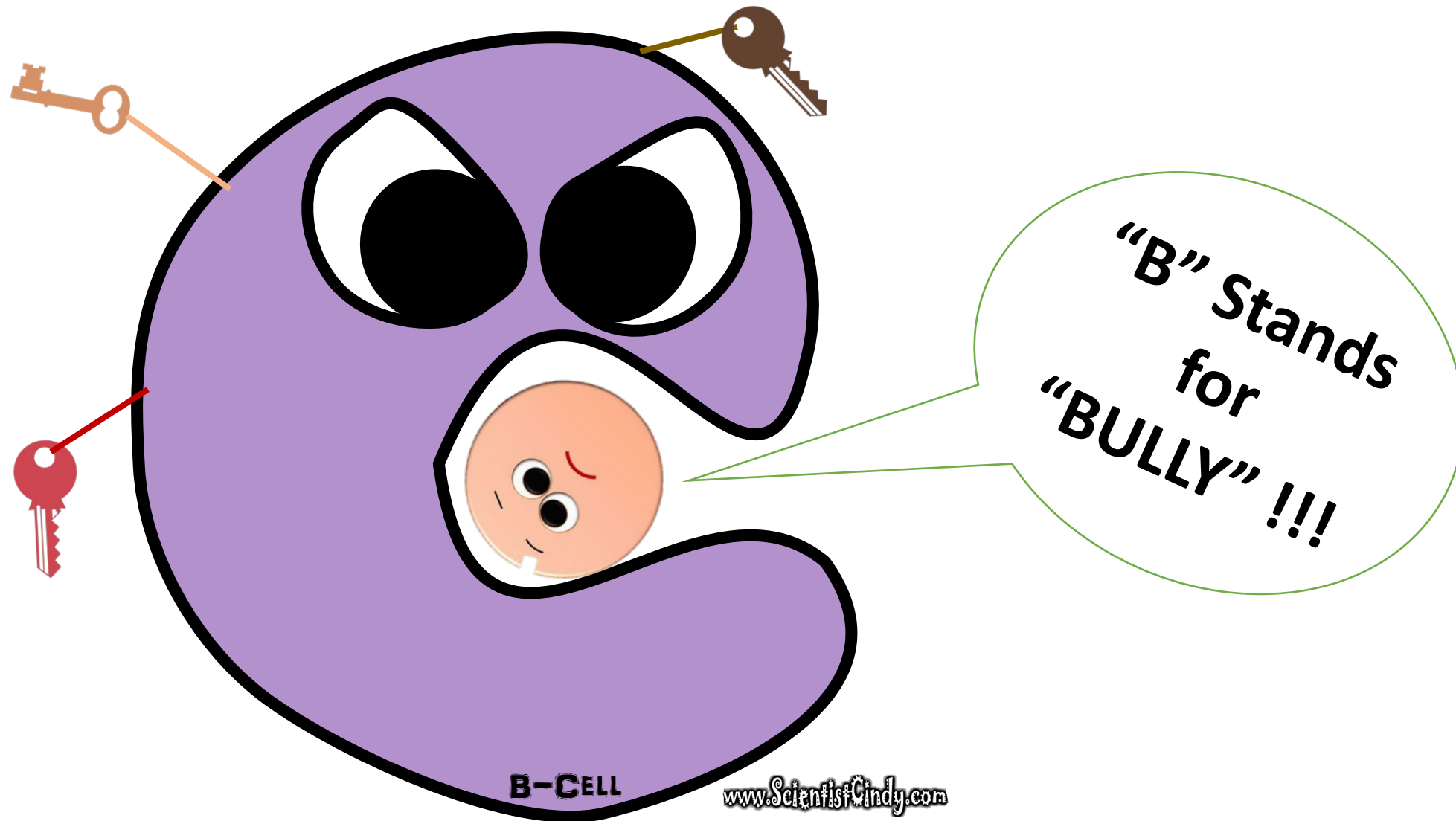


The B cell will keep trying different keys (antibodies) until it finds a MATCH!



B-CELL CARRYING ANTIBODIES

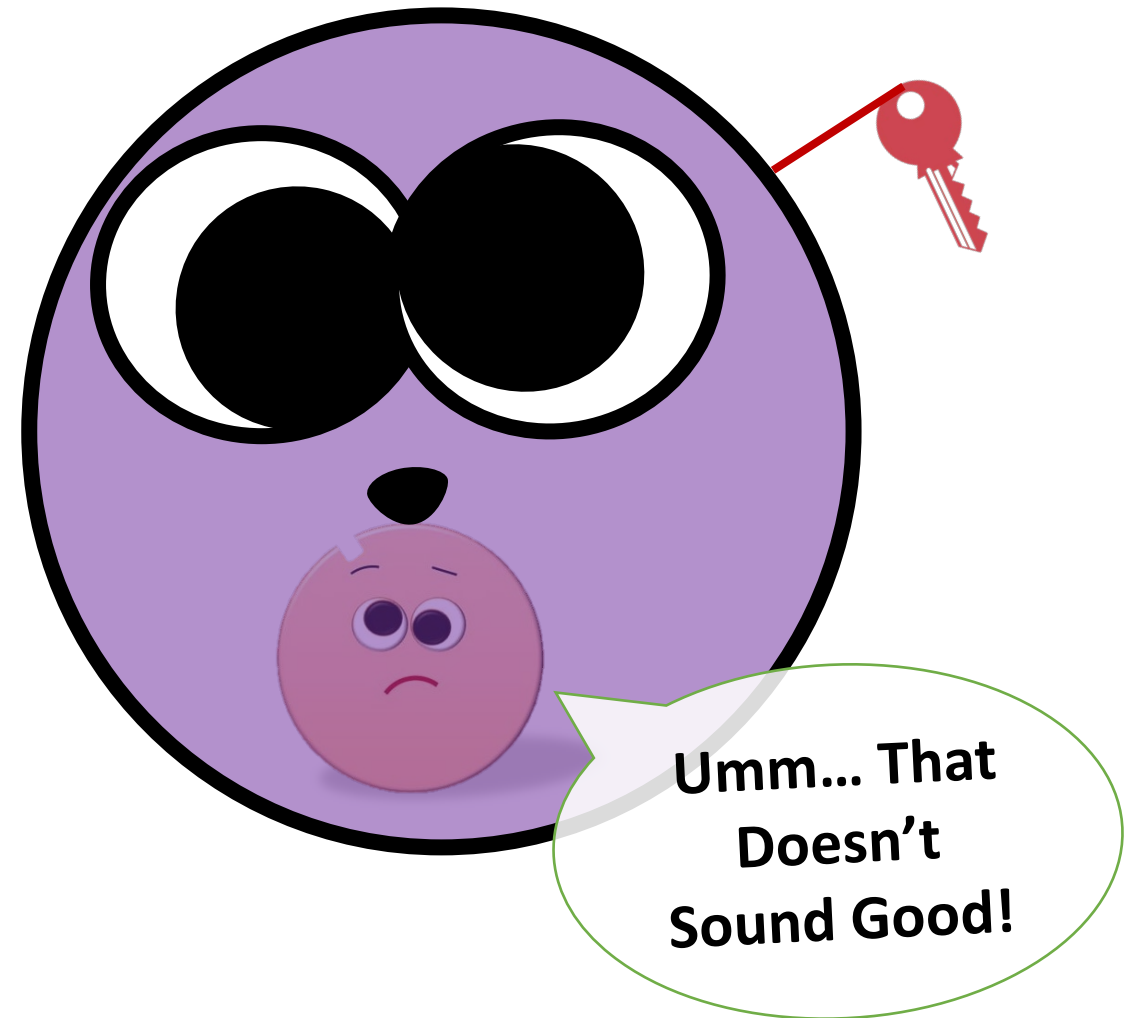
Once the B-Cell Finds a Match, it takes the antigen



Into itself Using Endocytosis

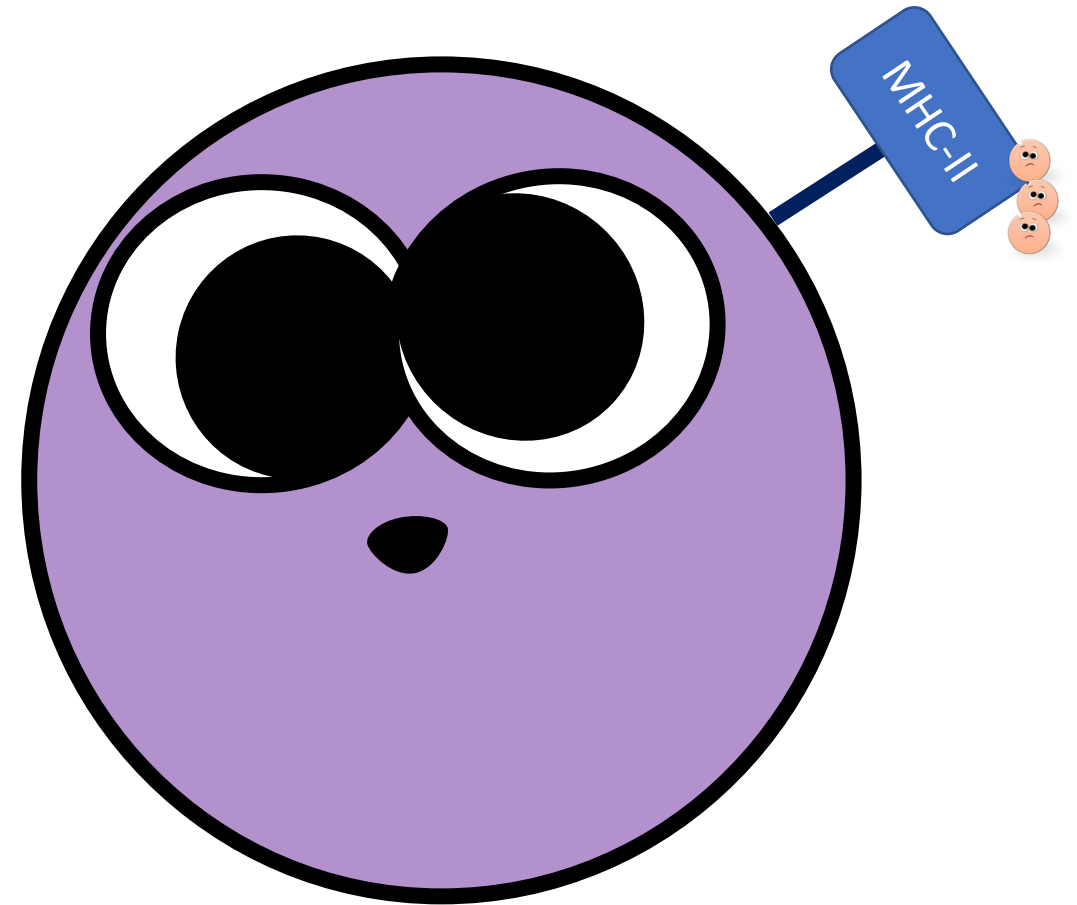
# The Antigen is Fragmented

- Once the antigen is inside of the B-Cell, the B-Cell will break down the antigen molecule into smaller fragments.

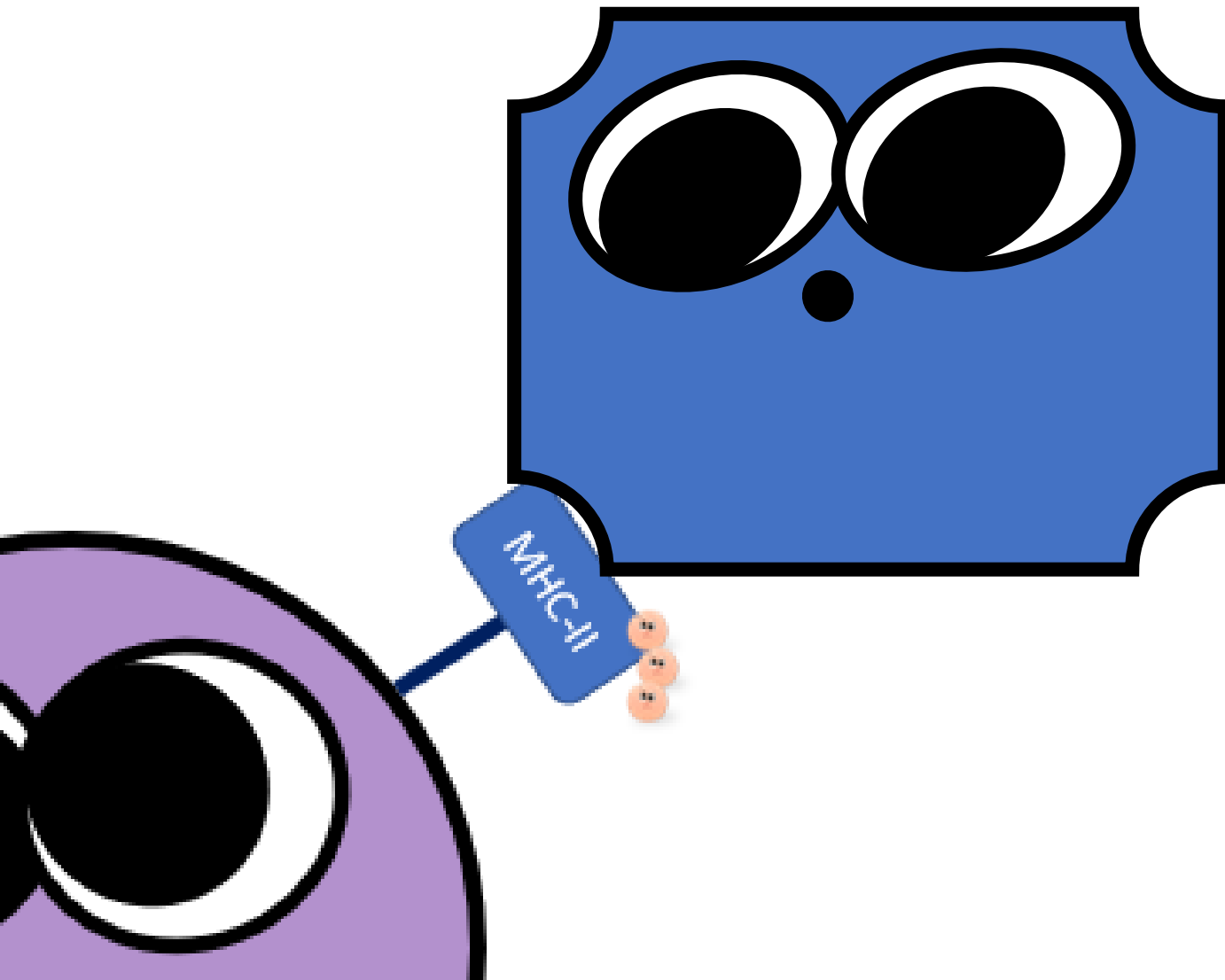


# MHC-II Molecules

- The B-Cell then uses these fragments to create MHC-II molecules that are displayed on the B-Cells Surface.
- At this stage, the B-Cell can also be called an “antigen-presenting cell”.



# The T-Cells

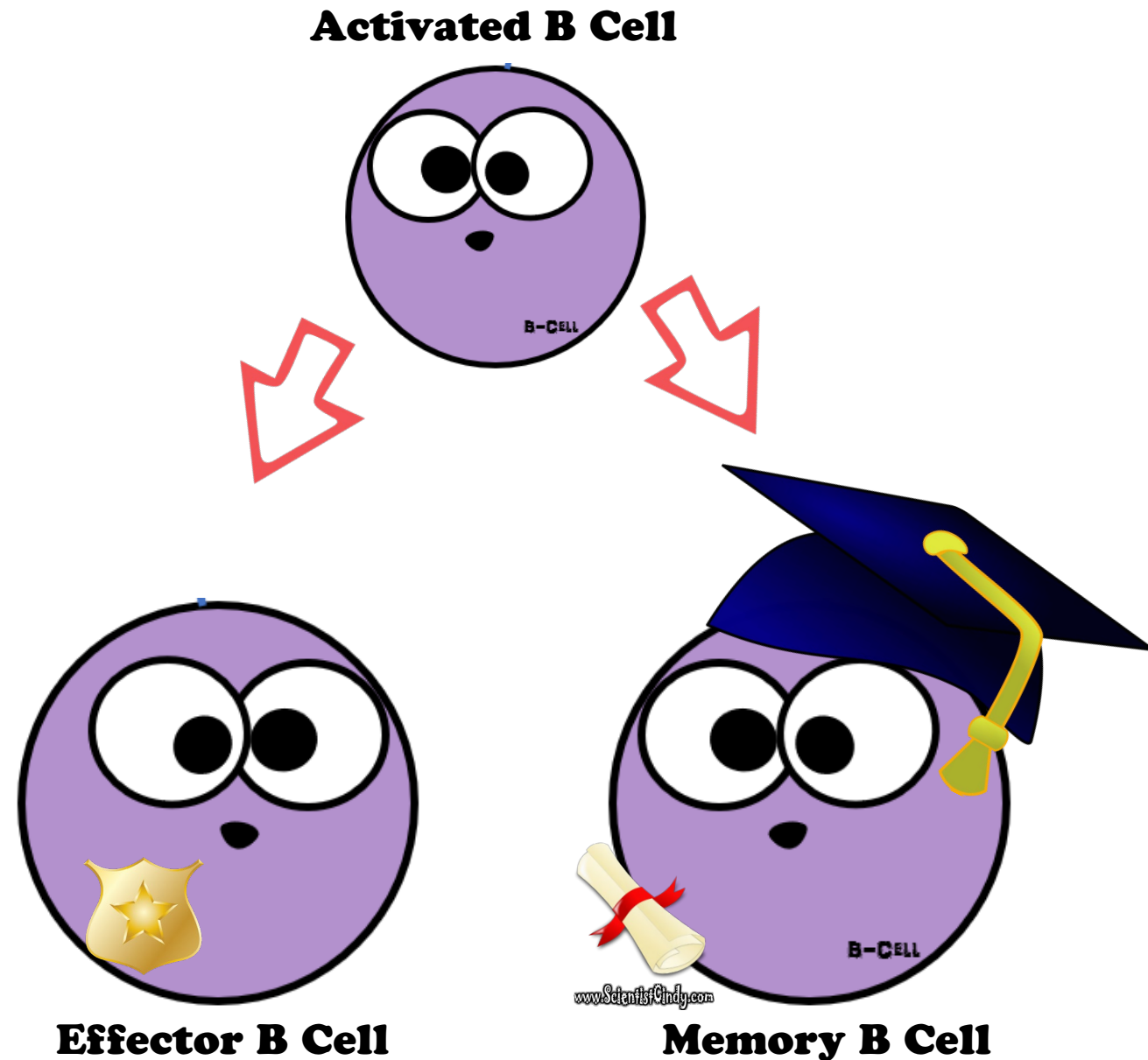


- The T cell will then bind to the MHC-II complex and become activated.
- The activated T cell releases cytokines that causes the B cells to undergo rapid cell division.



# B-Cell Activation → Proliferation

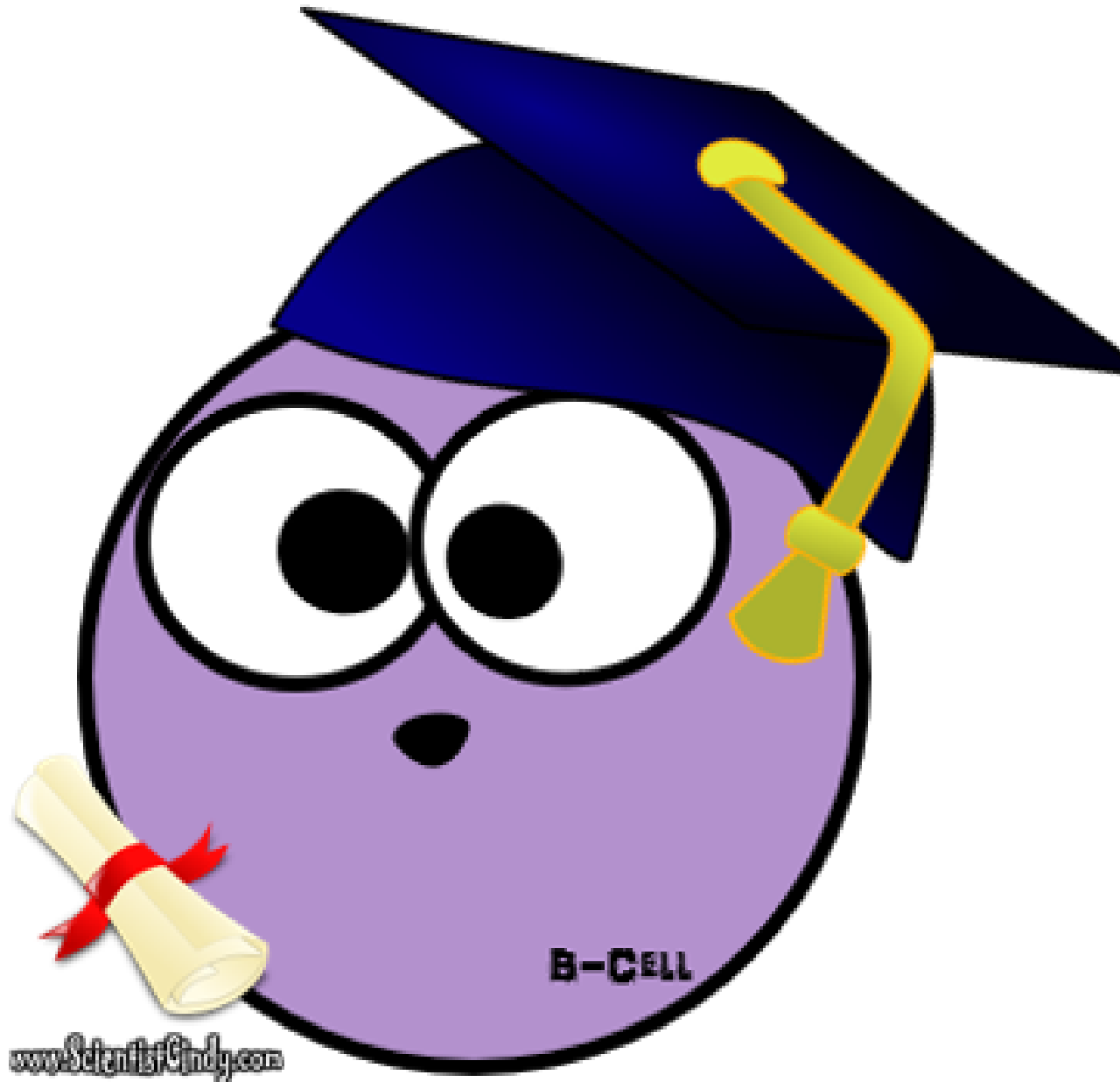
- The B-Cell begins to proliferate
- The B cell proliferates to form specialized
  1. memory B cells
  2. effector B cells



# MEMORY CELLS

Memory cells are involved in the **secondary immune response**.

**This means that** if this same antigen invades the body again in the future, thousands of memory B-Cells will be all ready to go and will quickly jump into action to destroy the invader!



**Memory B Cell**

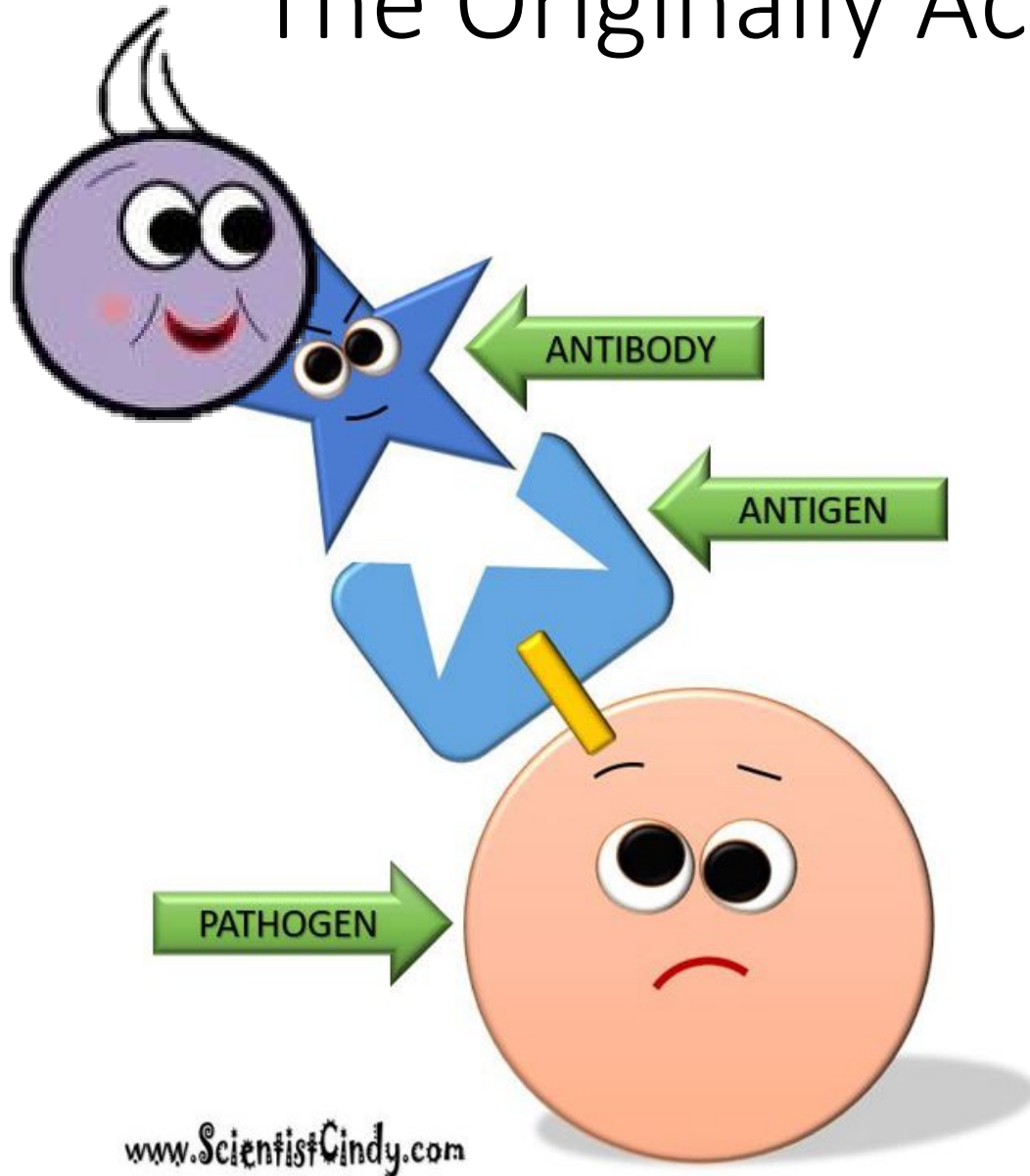


**Effector B Cell**

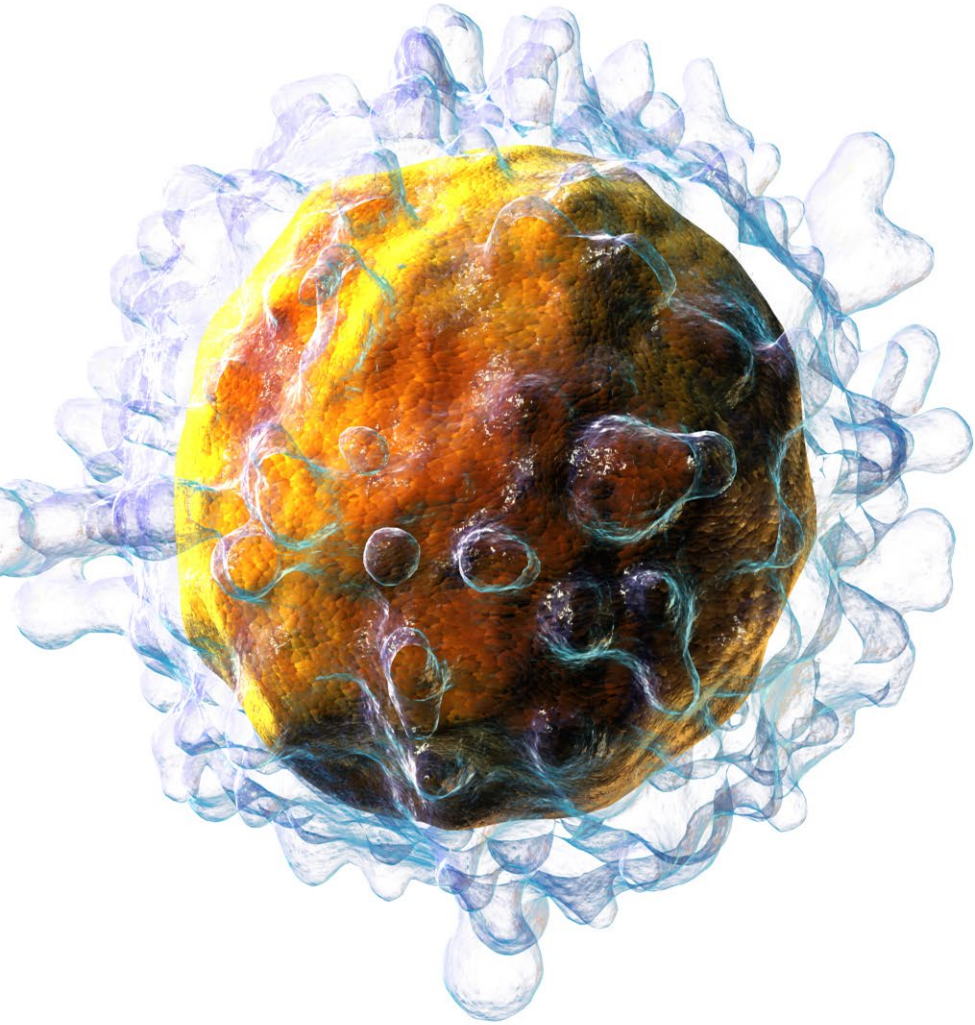
## Effector B-cells (Plasma Cells)

- The effector B-Cells (plasma cells) secrete millions of antibodies.
- These antibodies are able to bind to the antigen that caused the immune response.

# The Originally Activated B-cell



- The originally activated B-Cell Leaves the Secondary Lymphatic Organ that it has been residing in.
- The activated B-Cell then will circulate throughout the body's humors in search of more of these same antigens that it can bind to.
- When the B-Cell encounters an antigen, the B-Cell will lock onto it and act in a variety of ways that ultimately leads to the death of the invader.



# Lymphocyte

*T cell*

## Lymphocytes

---

Lymphocytes are the primary cells of adaptive immune responses.

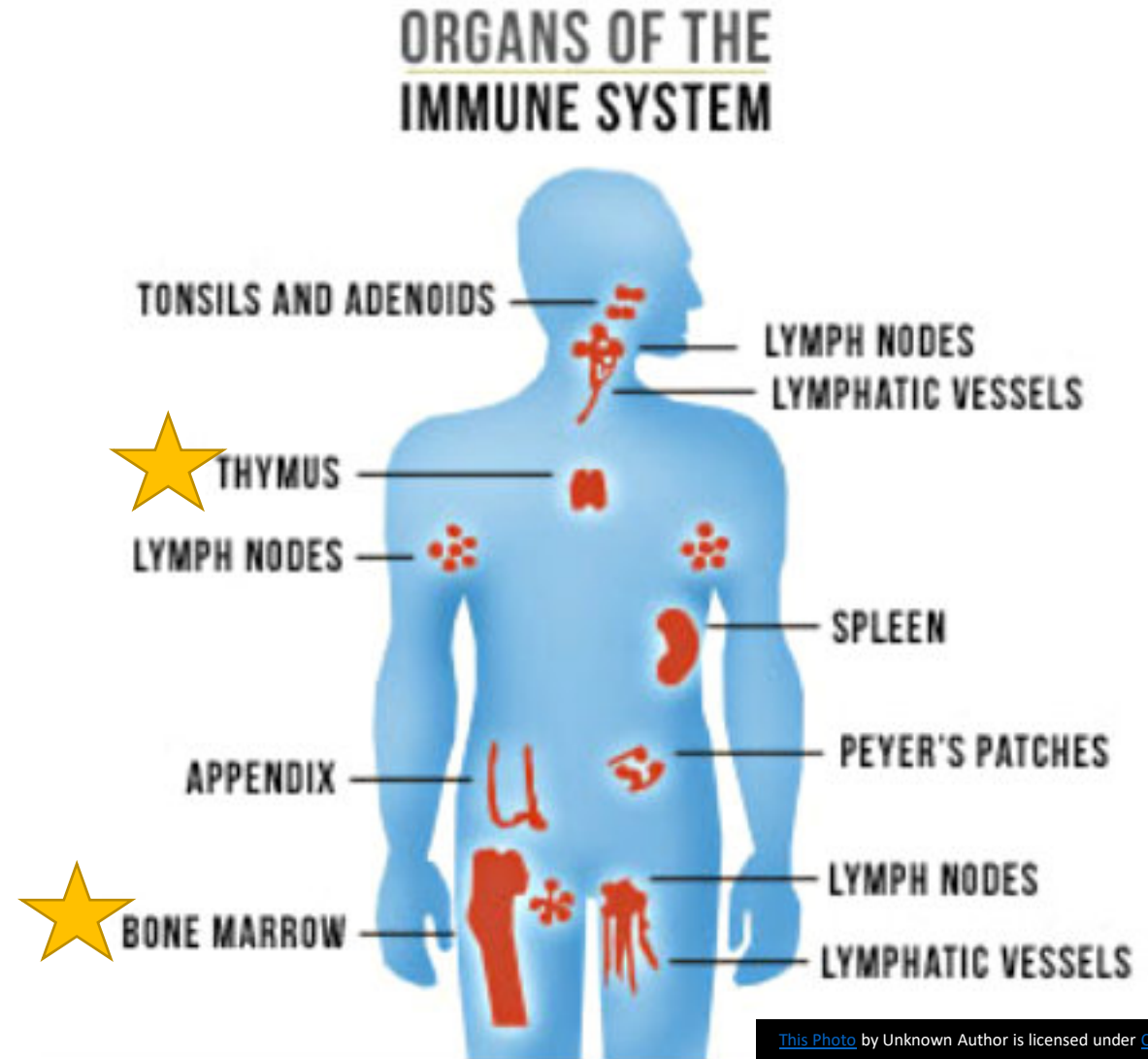
- The two basic types of lymphocytes are B cells and T cells
  - B cells develop and mature in red bone marrow
  - T cells mature in the thymus after being developed in the red bone marrow.

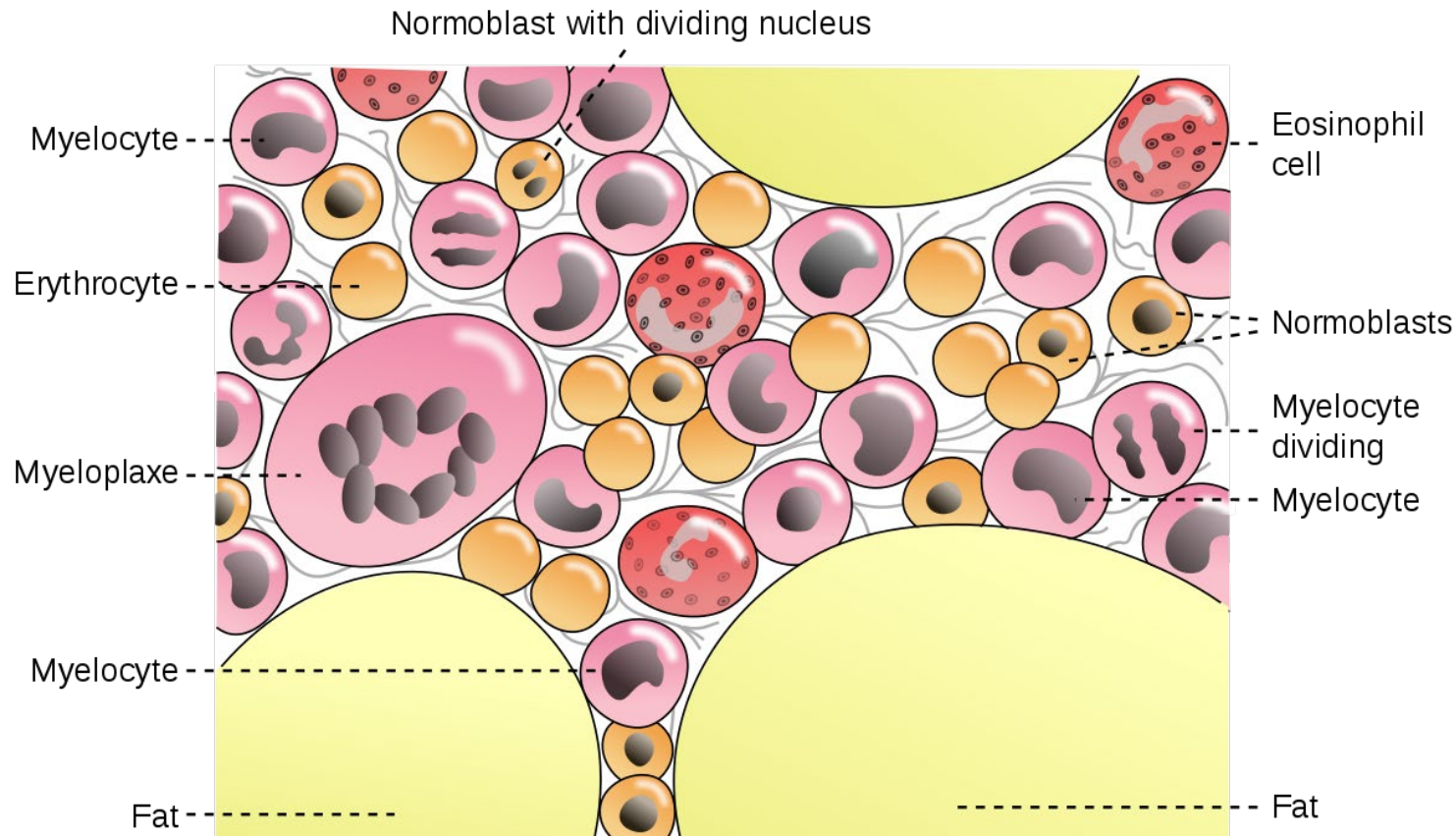
# Table 1. Lymphocytes

<b>TYPE OF LYMPHOCYTE</b>	<b>PRIMARY FUNCTION</b>
<b>B LYMPHOCYTE</b>	<b>GENERATES DIVERSE ANTIBODIES</b>
<b>T LYMPHOCYTE</b>	<b>SECRETES CHEMICAL MESSENGERS</b>
<b>PLASMA CELL</b>	<b>SECRETES ANTIBODIES</b>
<b>NK CELL</b>	<b>DESTROYS VIRALLY INFECTED CELLS</b>

## Primary Lymphoid Organs

The lymphoid organs are where lymphocytes mature, proliferate, and are selected, which enables them to attack pathogens without harming the cells of the body.





## Bone Marrow

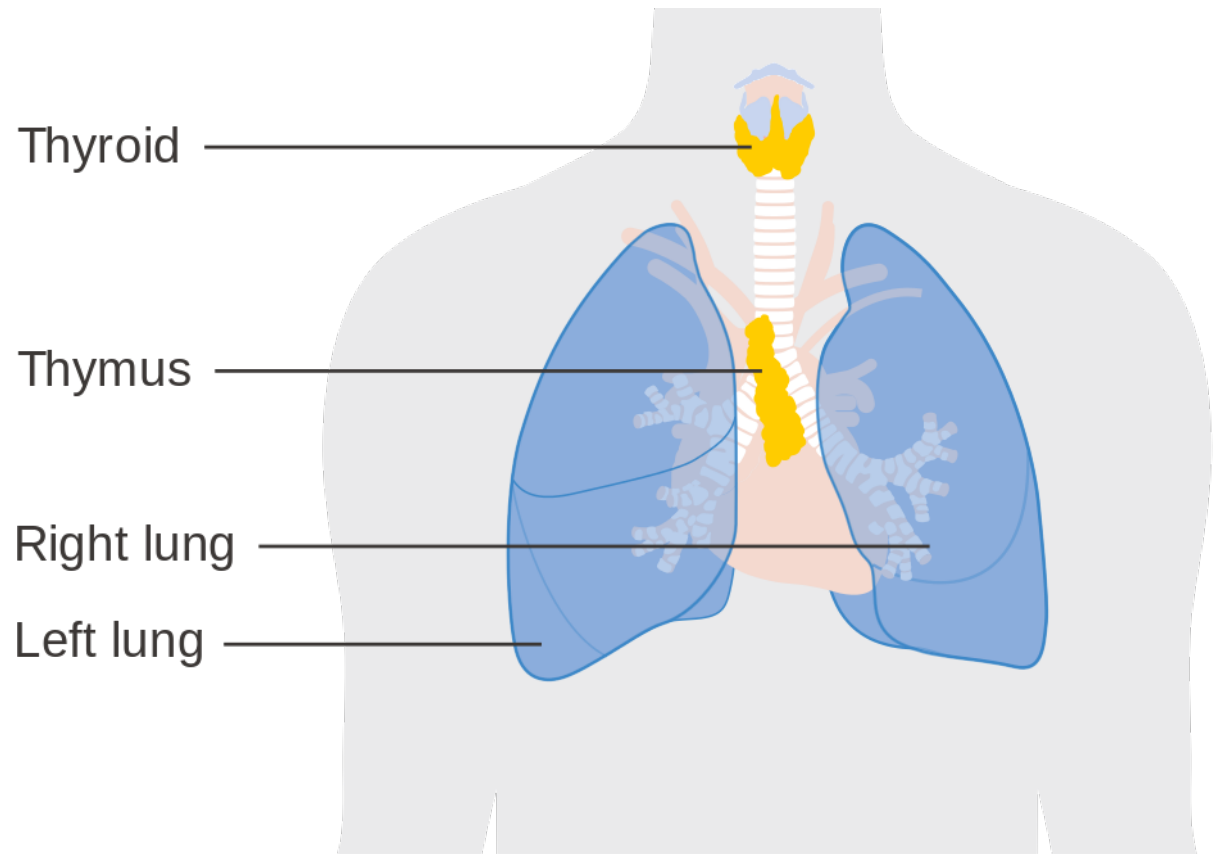
Initial development of the white blood cells (including B cells and T cells) occurs in the red bone marrow.

- The B cells undergo maturation in the red bone marrow.
- The T cells undergo maturation in the thymus gland.



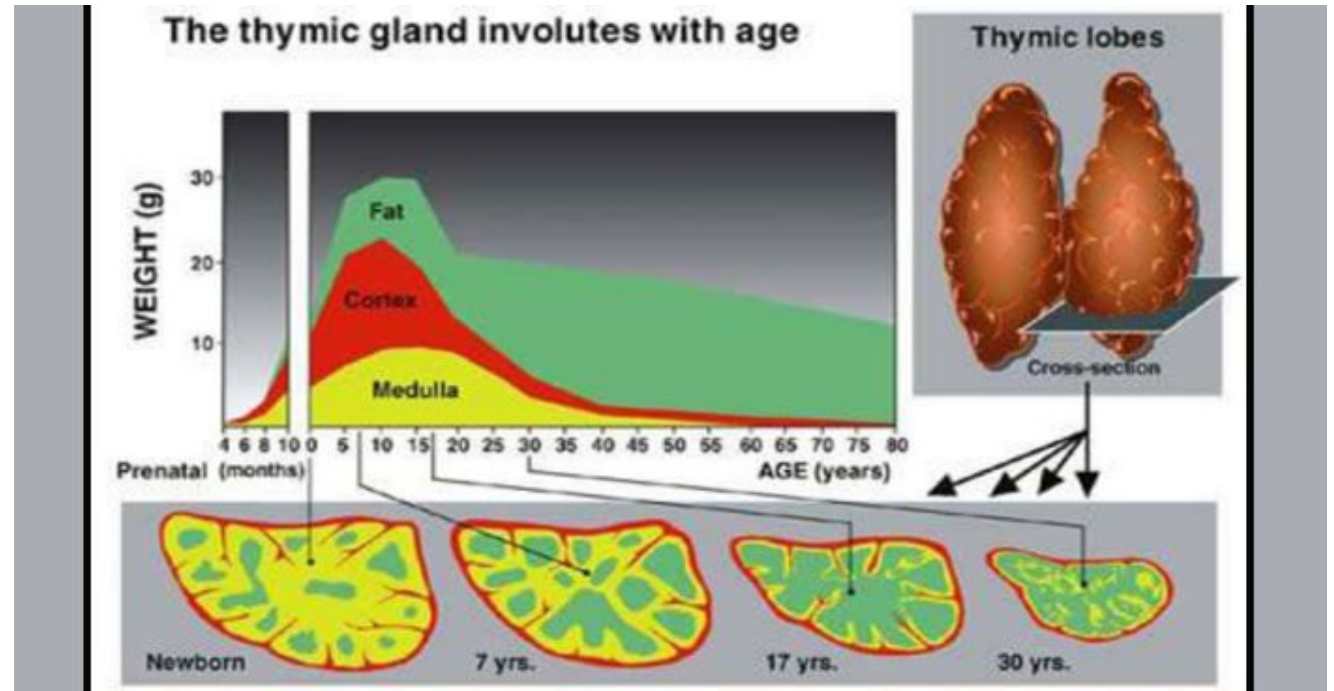
# Thymus

- The thymus gland is a bi-lobed organ found in the space between the sternum and the aorta of the heart.
- Connective tissue holds the lobes closely together but also separates them and forms a capsule.



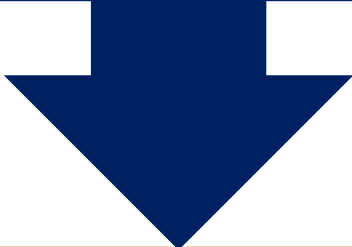
# THYMIC INVOLUTION

- One major cause of age-related immune deficiencies is **thymic involution**.
- The shrinking of the thymus gland that begins at birth, at a rate of about three percent tissue loss per year, and continues until 35–45 years of age, when the rate declines to about one percent loss per year for the rest of one's life.
- At that pace, the total loss of thymic epithelial tissue and thymocytes would occur at about 120 years of age.



# Secondary Lymphoid Organs and their Roles in Active Immune Responses

Lymphocytes circulate in the blood and lymph, and are concentrated in secondary lymphoid organs



The secondary lymphatic organs include the...

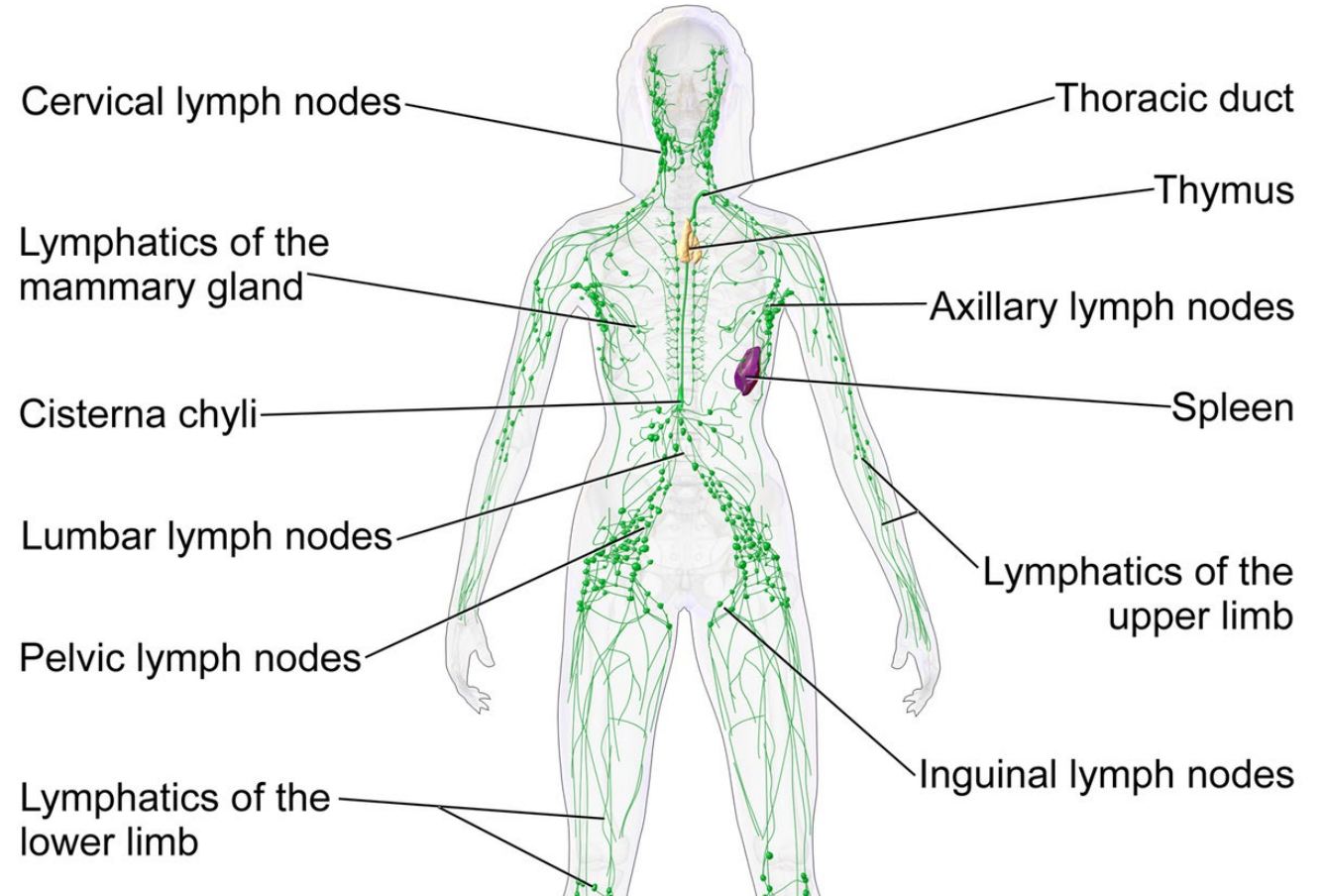
Lymph nodes

Spleen

Lymphoid nodules.

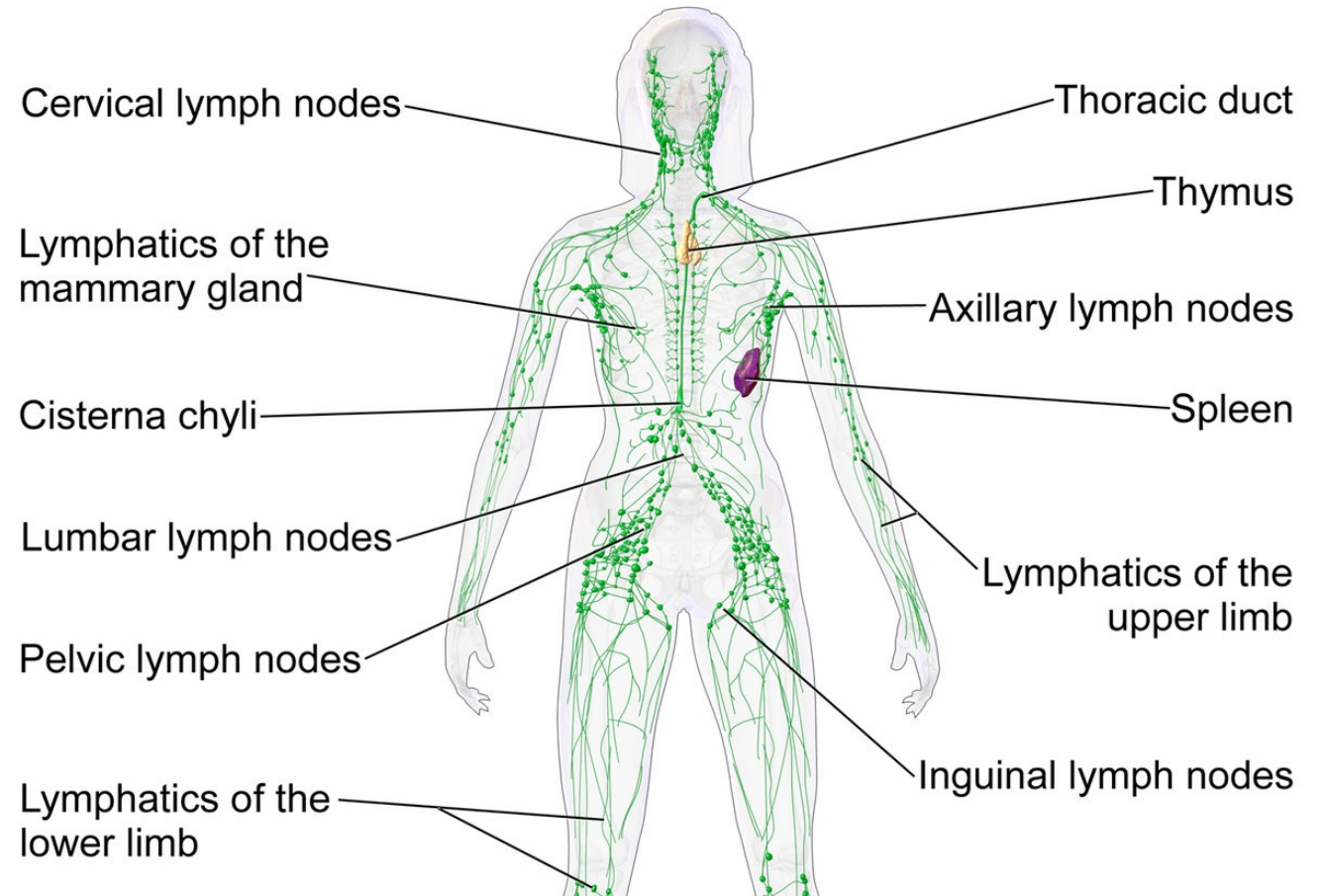
## LYMPH NODES

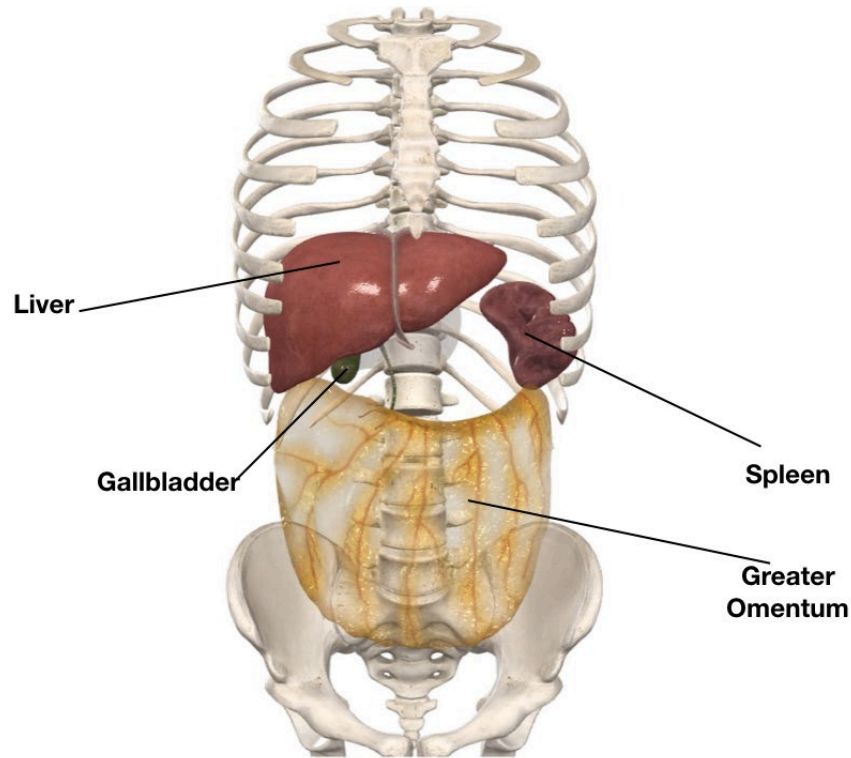
- *Lymph nodes are the “filters of the lymph”.*
- *Lymph Nodes*
  - *Remove debris*
  - *Fights pathogens*
- *Bacteria that infect the interstitial fluid are taken up by the lymphatic capillaries and transported to a regional lymph node.*
- *Dendritic cells and macrophages kill many of the pathogens*



## LYMPH NODES

- *The lymph nodes act as sites of the adaptive immune responses mediated by T cells, B cells, and accessory cells of the adaptive immune system.*



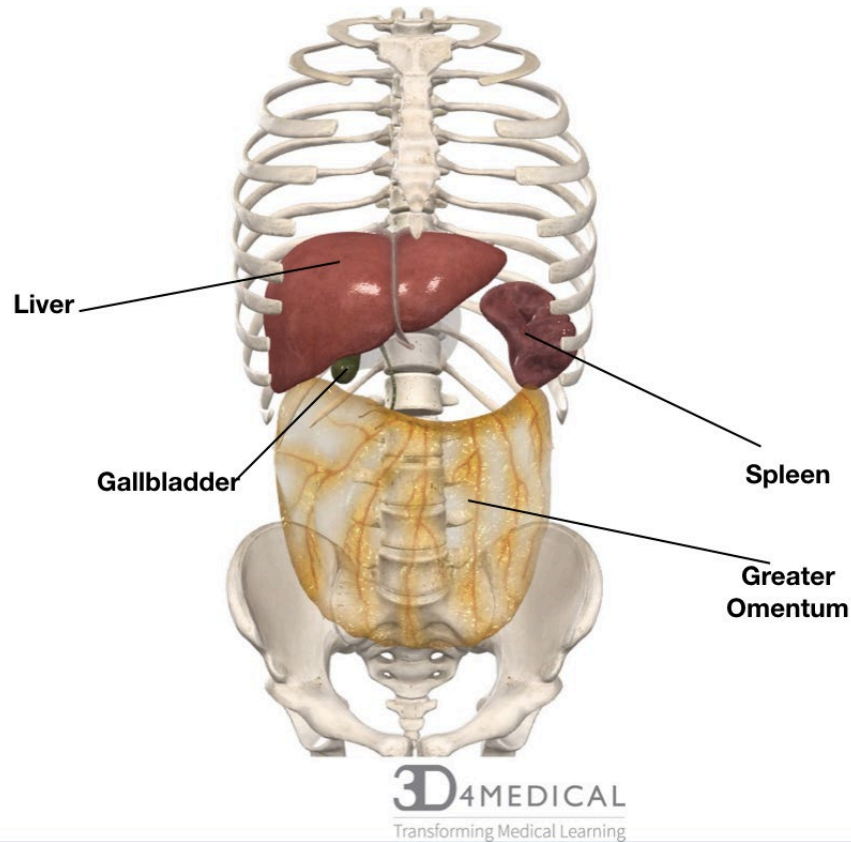


**3D**4MEDICAL  
Transforming Medical Learning

The spleen is a major secondary lymphoid organ.

- It is attached to the left lateral border of the stomach.
- The spleen is a fragile organ without a strong capsule, and is dark red due to its extensive vascularization.

# The Spleen

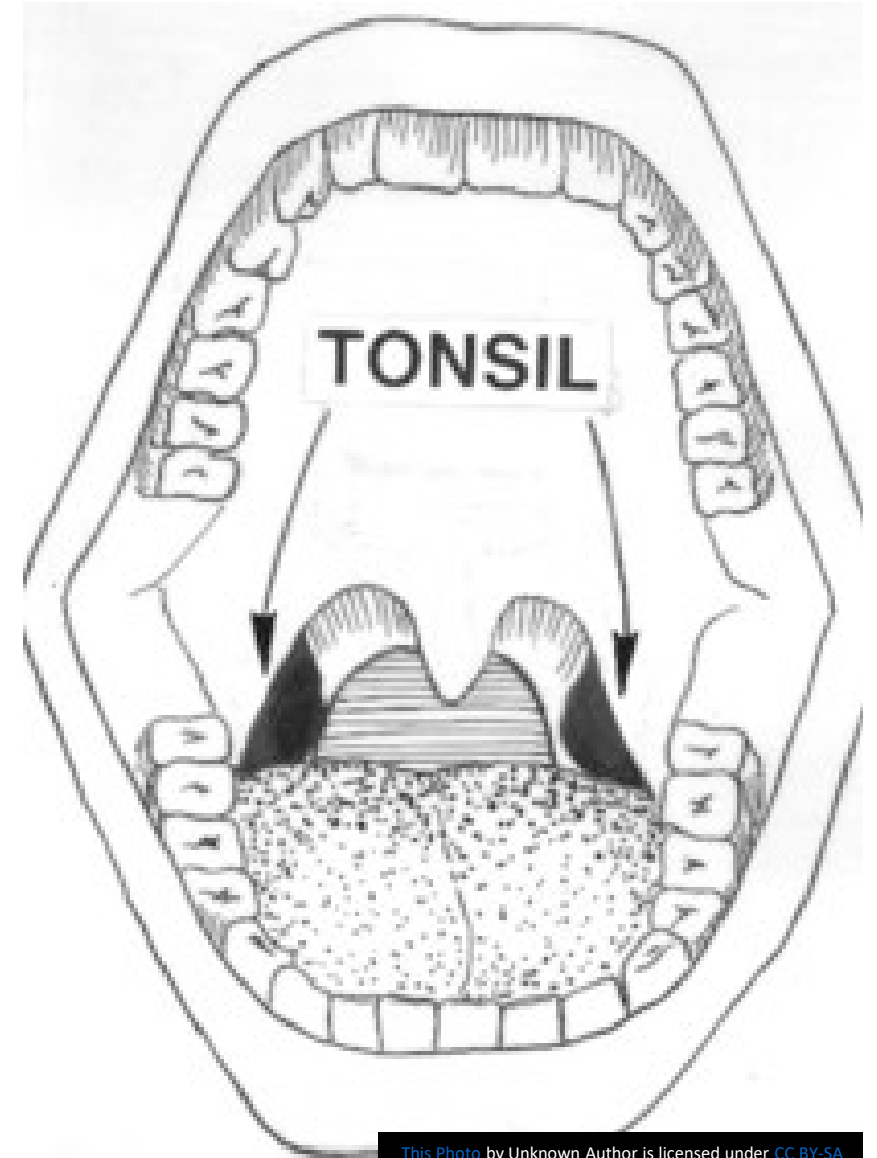


- The spleen is sometimes called the “filter of the blood”.
  - Extensive vascularization
  - Has macrophages and dendritic cells
    - Act to remove microbes and other materials from the blood, including dying red blood cells.
  - The spleen also functions as the location of immune responses to blood-borne pathogens.

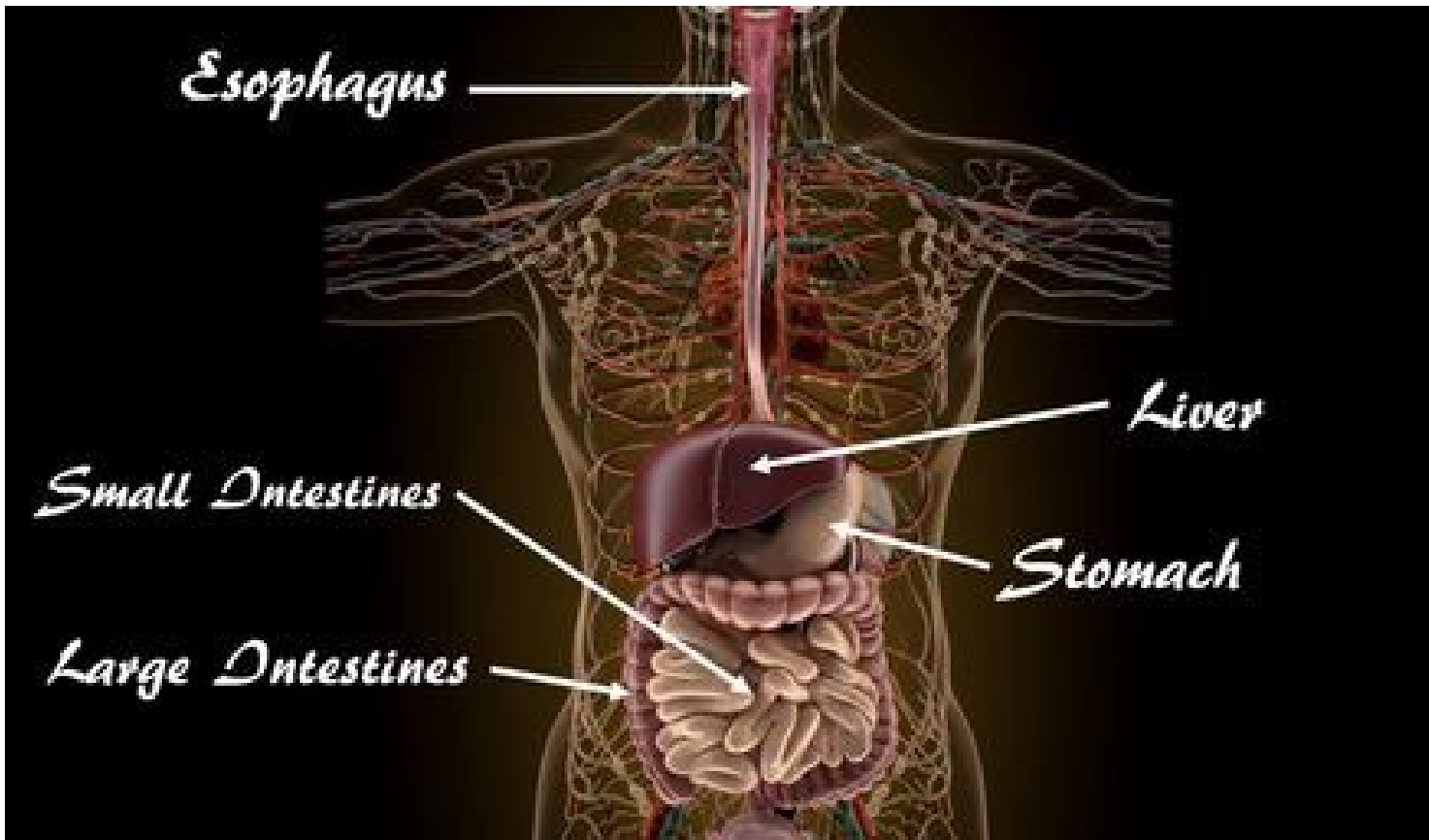
# The Spleen

# Lymphoid Nodules

- The lymphoid nodules consist of a dense cluster of lymphocytes.
- Lymphoid nodules are located in the respiratory and digestive tracts.
- Tonsils are lymphoid nodules located along the inner surface of the pharynx (throat) and are important in fighting pathogens.
- Tonsil swelling is an indication of an active immune response to infection.







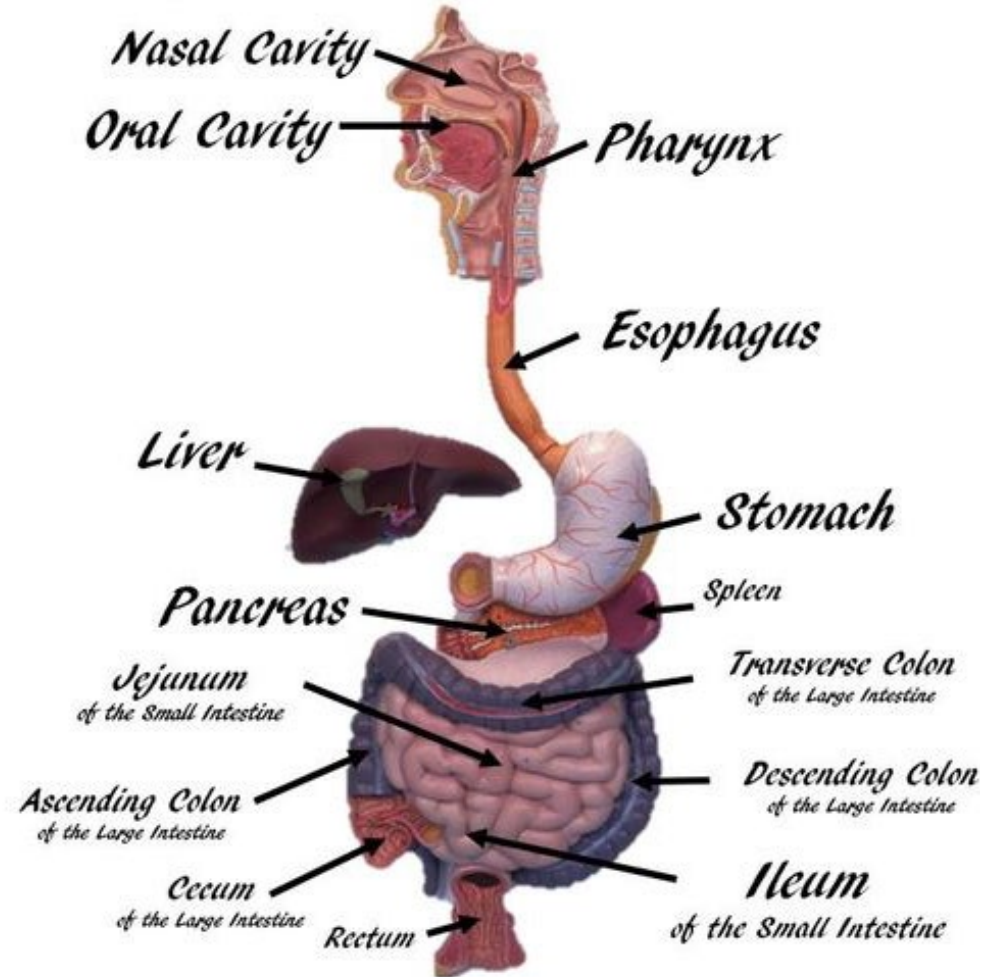
## *What is the Digestive System?*

- The digestive system works to convert the food we eat into smaller units our body can absorb and use. It achieves this by
  - 1) Take in food
  - 2) Break food up into nutrient molecules
  - 3) Absorbing nutrient molecules into the circulatory system
  - 4) Eliminating the indigestible waste

# The Digestive Tract / Gastrointestinal Tract / The Alimentary Canal

- The alimentary canal gets its names from a word meaning "nourishment".
- The alimentary canal is better known as the gastrointestinal (or G.I.) tract.
- The alimentary canal is a continuous tube lined with smooth muscle that extends from the mouth to the anus.
- **Your body is organized as a tube. The inside of the alimentary canal is considered to be OUTSIDE of the body! This is because both ends of the canal are exposed to the external environment. If you were to stretch out your alimentary canal, it would reach up to about 30 feet in length!**

## *Digestive System Anatomical Model*



# The organs of the digestive system perform the following six activities:

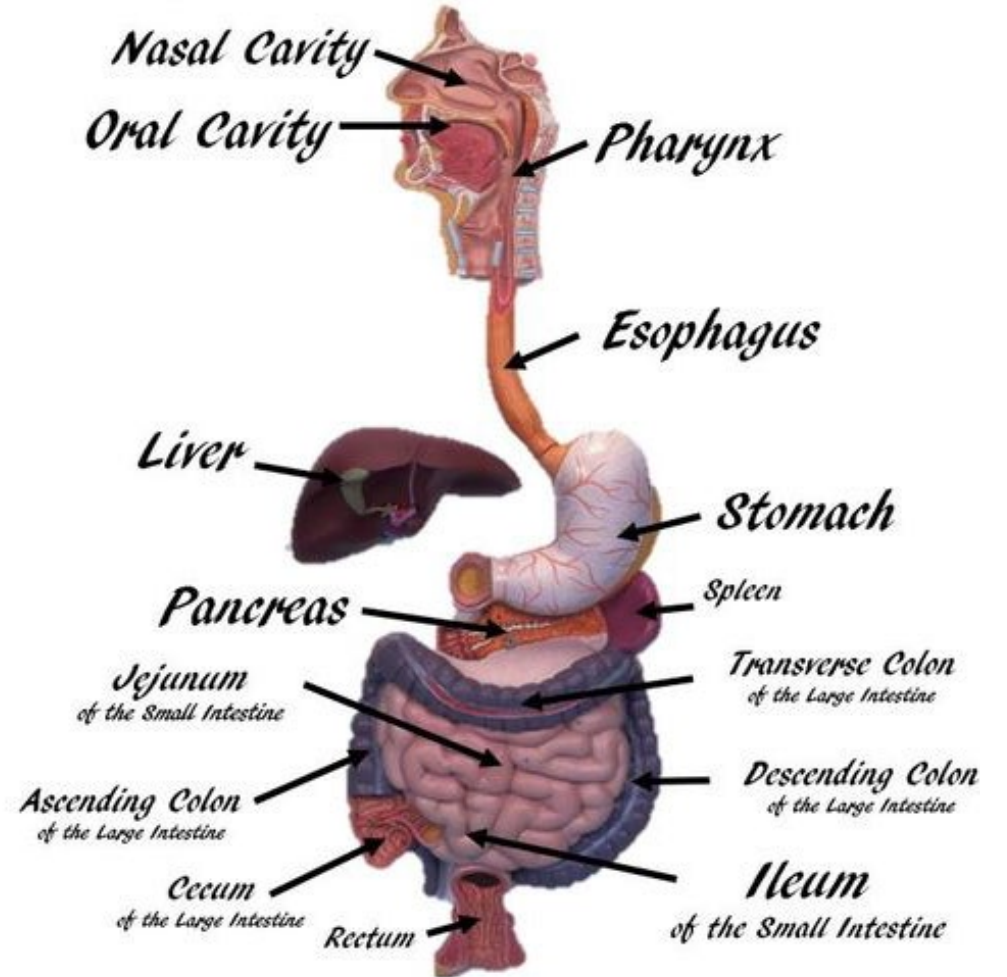
1. The organs of the digestive system perform the following six activities: Ingestion - taking of food into the mouth.
2. Propulsion - movement of food through the alimentary canal
  - Swallowing (voluntary)
  - Peristalsis - moves food through the alimentary canal by waves of involuntary contraction and relaxation of smooth muscle
3. Mechanical - the physical processes that break up larger pieces of food into smaller pieces.
  - Chewing
  - Churning processes of the stomach
  - Rhythmic contraction and relaxation (peristalsis) of smooth muscle of the small intestine.
4. Digestion - the chemical decomposition of carbohydrates, proteins, and lipids into their simpler building blocks (simple sugars, amino acids, and fatty acids or glycerol, respectively). Digestion is carried out by digestive enzymes and other substances secreted by the accessory organs. The processes of digestion take place in the lumen of the alimentary canal.
5. Absorption - the transportation of digested food from the lumen of the alimentary canal into the blood and lymphatic capillaries located in the wall of the canal.
6. Defecation - the elimination of indigestible substances (wastes) from the body as feces.

The digestive system is divided into two main groups: the alimentary canal and the accessory digestive organs.

The organs that make up the alimentary canal are as follows:

- Mouth
- Pharynx
- Esophagus
- Stomach
- Small Intestine (small bowel)
- Large Intestine (large bowel)

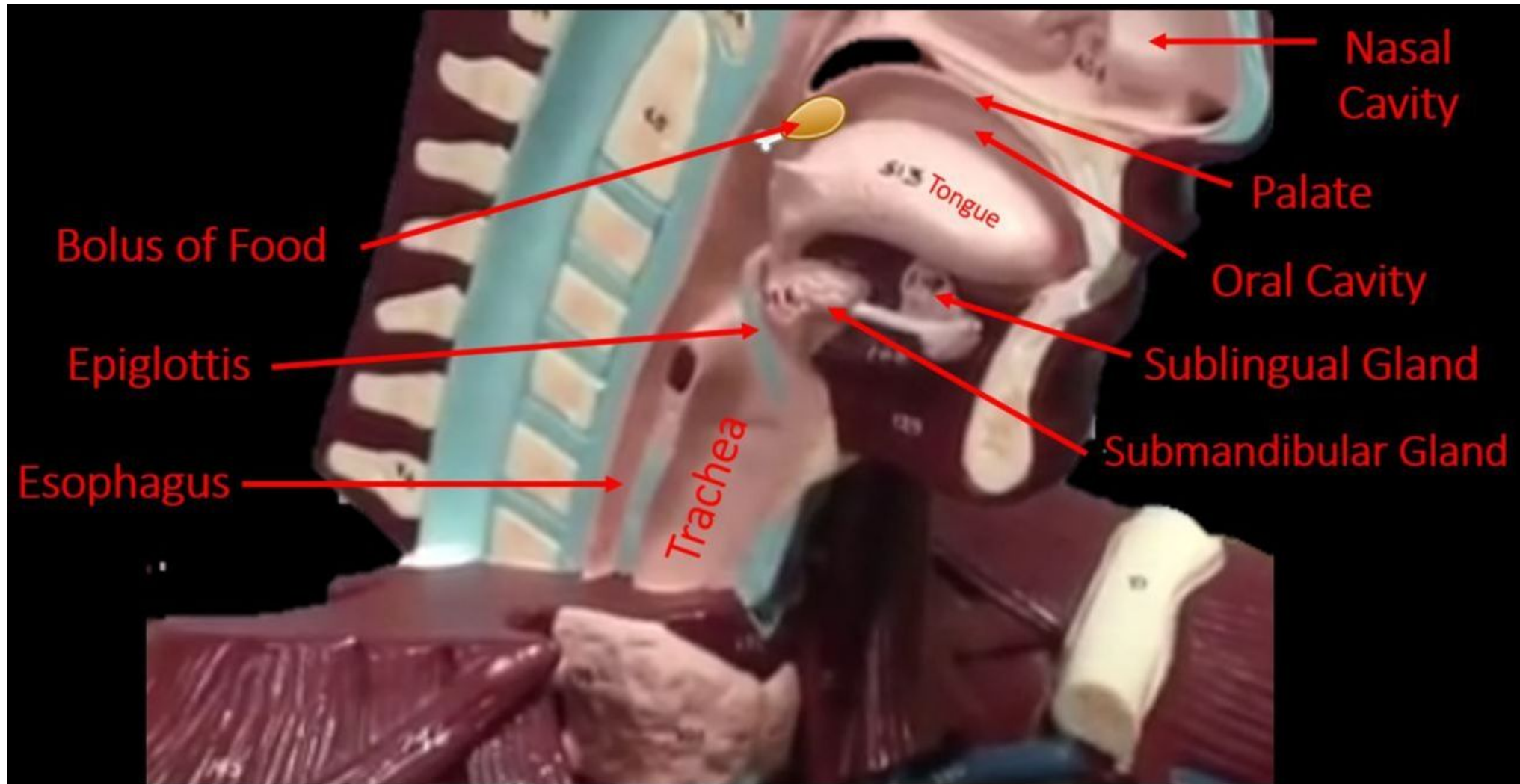
## *Digestive System Anatomical Model*

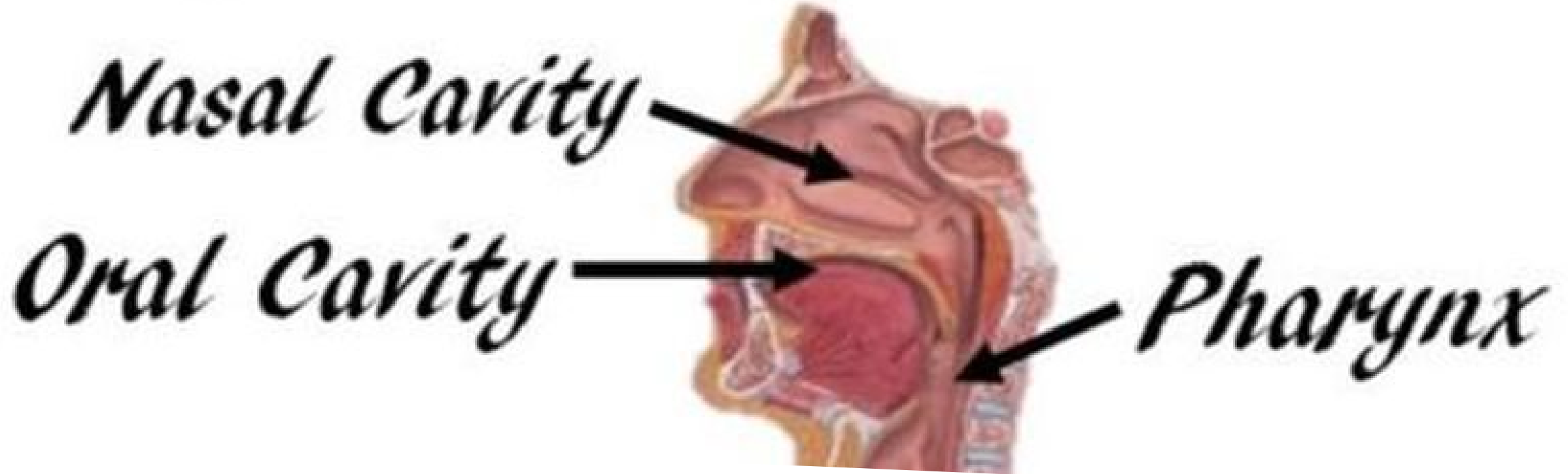


# THE ACCESSORY DIGESTIVE ORGANS

- **The digestive system includes the accessory digestive organs which are as follows:**
- **Teeth**
- **Tongue**
- **Gallbladder**
- **The Large Digestive Glands**
  - **The Salivary Glands**
  - **The Liver**
  - **The Pancreas**
- **The accessory digestive organs function to secrete saliva, bile, and digestive enzymes, that assist to breakdown food.**

# Digestive System Structures of the Head and Neck





## The Oral Cavity

- The oral cavity (or mouth) contains the teeth, the cheek, the palate and the anterior portion of the tongue. The opening of the mouth is referred to as the oral orifice. The mouth functions to take in food and to contain structures needed for mastication. It also houses the tongue to sense, taste and it assists in the formation of words and sounds for speech.

Food enters the alimentary canal through the mouth. Food in the mouth is mechanically broken down by chewing and manipulation of the tongue.

# The Salivary Glands

- **The food is moistened with saliva to form a bolus of food, that is able to be swallowed.** The saliva also contains digestive enzymes which begin to chemically break down some food substances.



# The Salivary Glands

- **The salivary glands produce saliva. Saliva is necessary to moisten food to create a bolus (moist ball of food that can be swallowed).**

**The parotid gland is found outside of the cheek, the sublingual gland lies under the tongue and the submandibular gland lies under the mandible (jaw).**

# The Salivary Glands

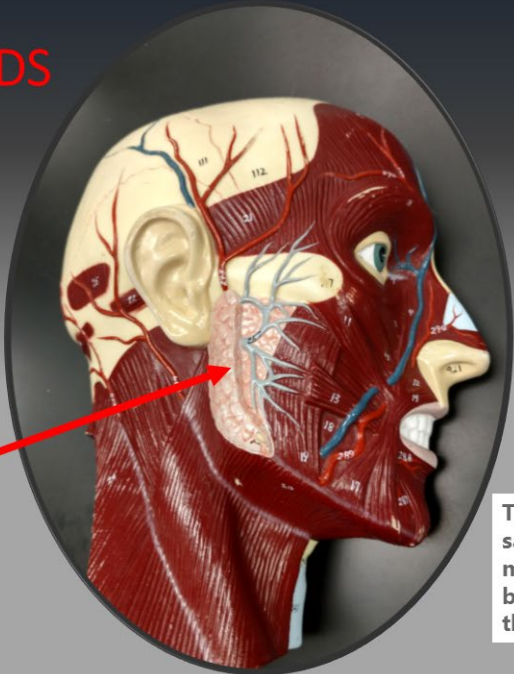
## SALIVARY GLANDS



Submandibular Gland

The salivary glands produce saliva. Saliva is necessary to moisten food to create a bolus (moist ball of food that can be swallowed).

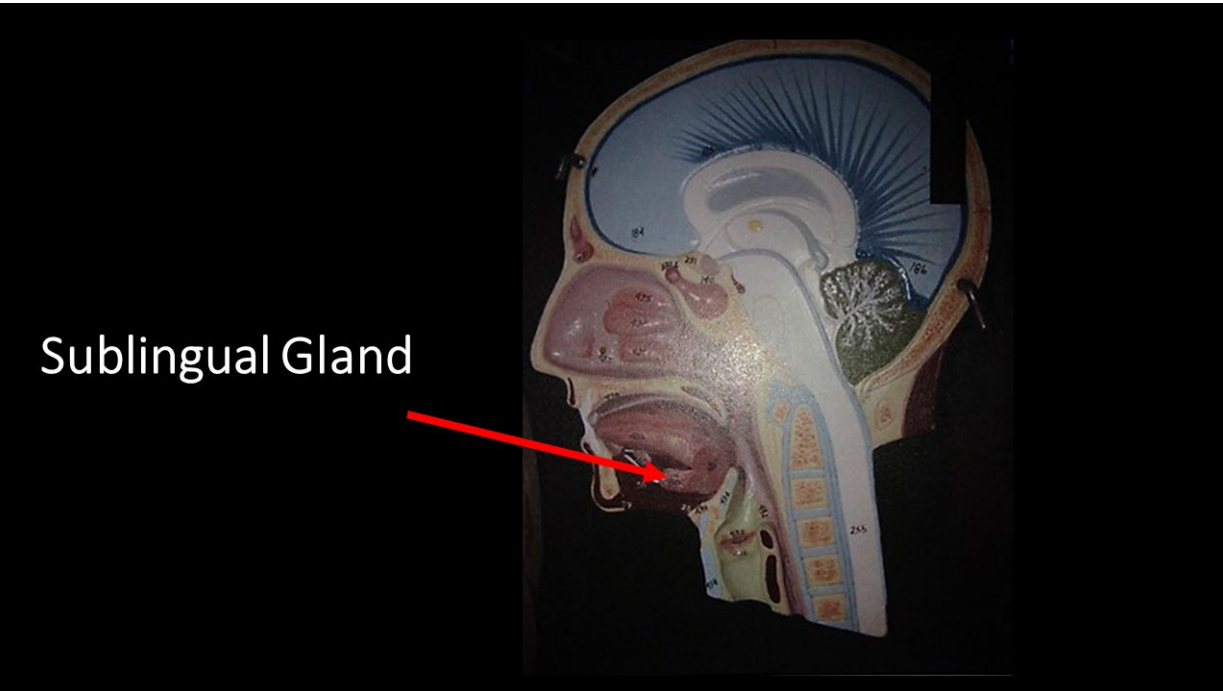
## SALIVARY GLANDS



Parotid Gland

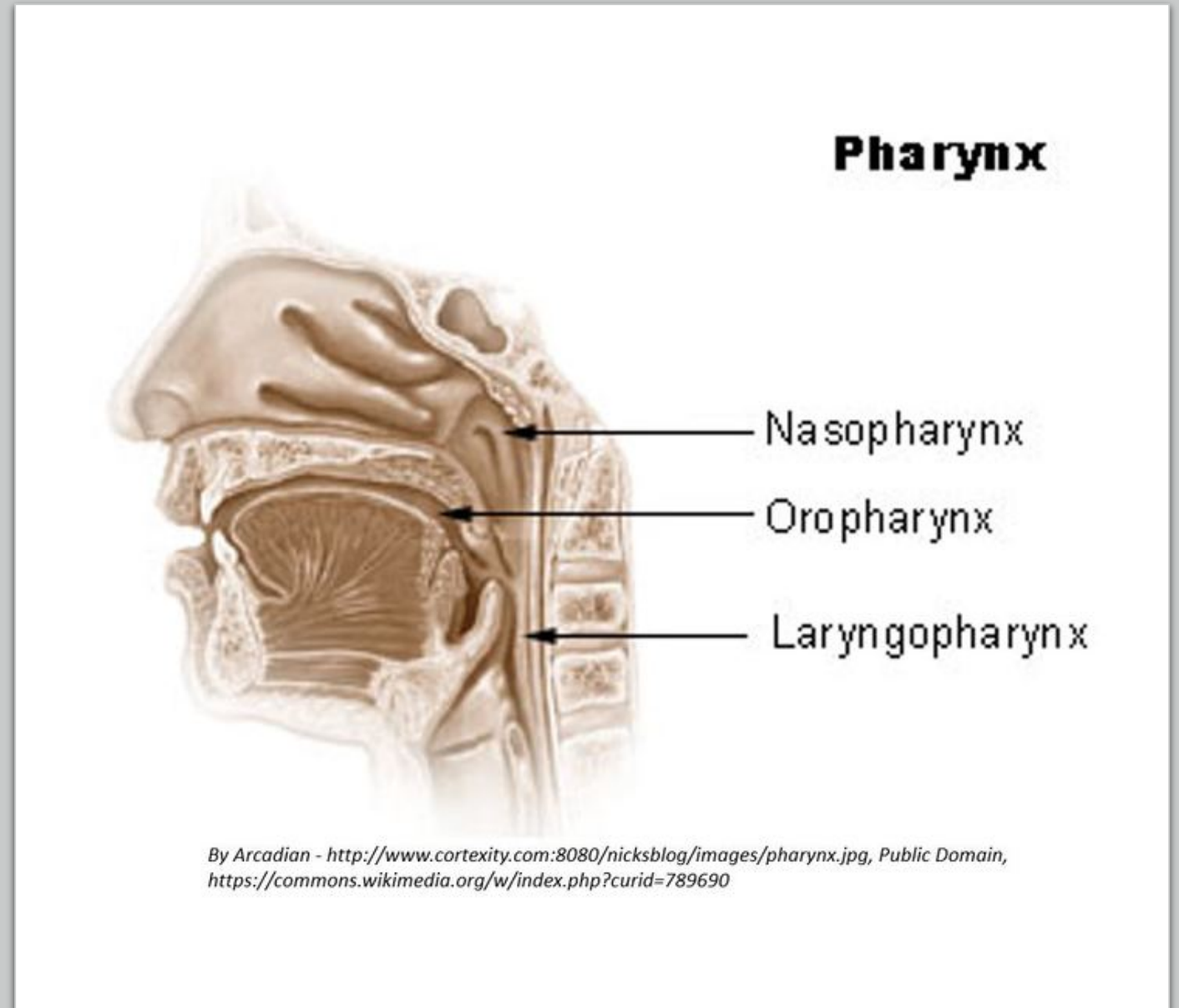
The salivary glands produce saliva. Saliva is necessary to moisten food to create a bolus (moist ball of food that can be swallowed).

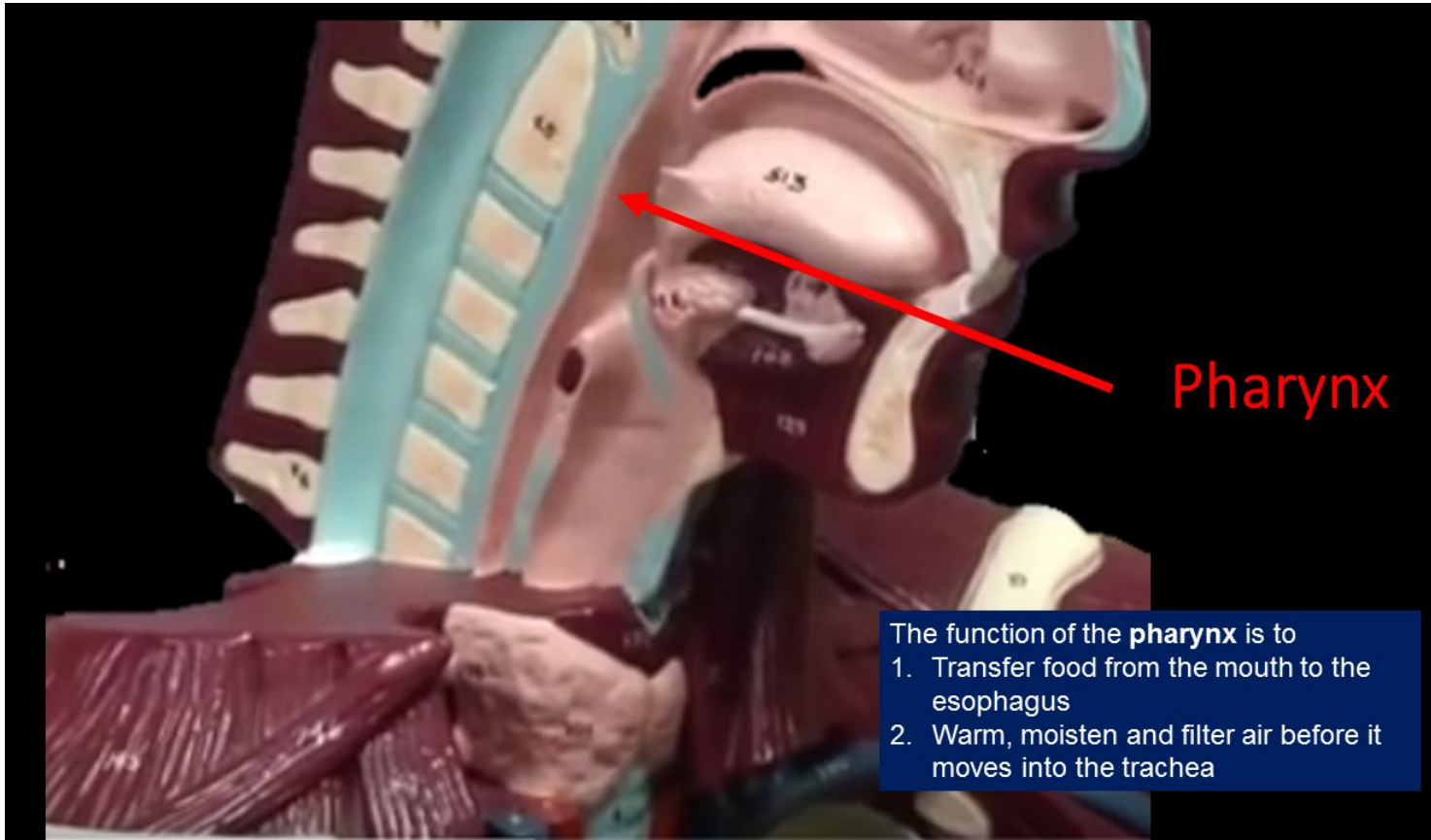
## Sublingual Gland



# Pharynx (Throat)

- The pharynx is better known as *the throat*. The throat leads from the nose cavity and the mouth cavity to the esophagus and the trachea. Pharynx is subdivided into the following three sections;
  - 1) the nasopharynx
  - 2) the oropharynx
  - 3) thr laryngopharynx.





Pharynx

The function of the **pharynx** is to

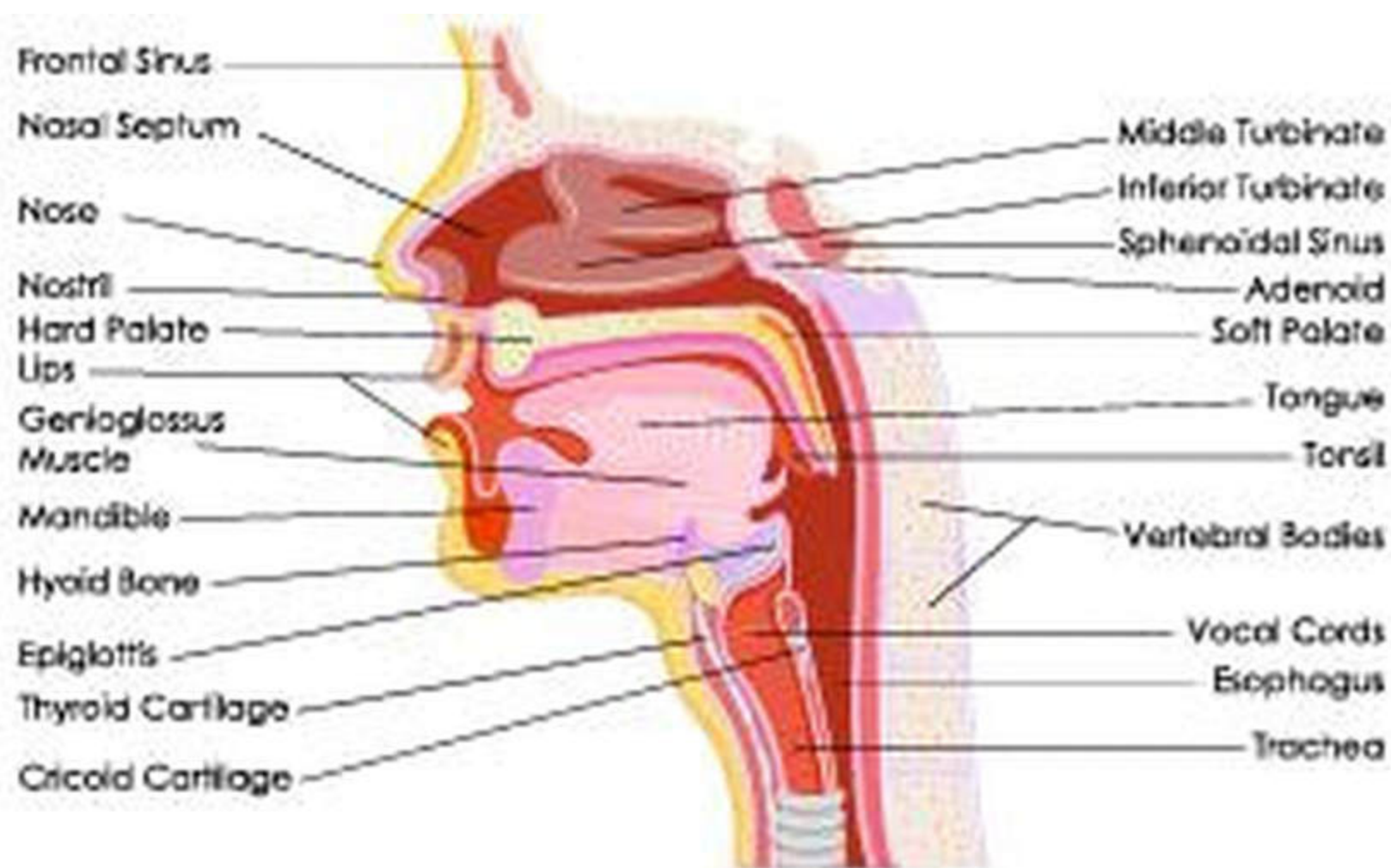
1. Transfer food from the mouth to the esophagus
2. Warm, moisten and filter air before it moves into the trachea

- The pharynx has 2 functions:
  - 1) to warm, moisten and filter air before it reaches the trachea
  - 2) to deliver food to esophagus.

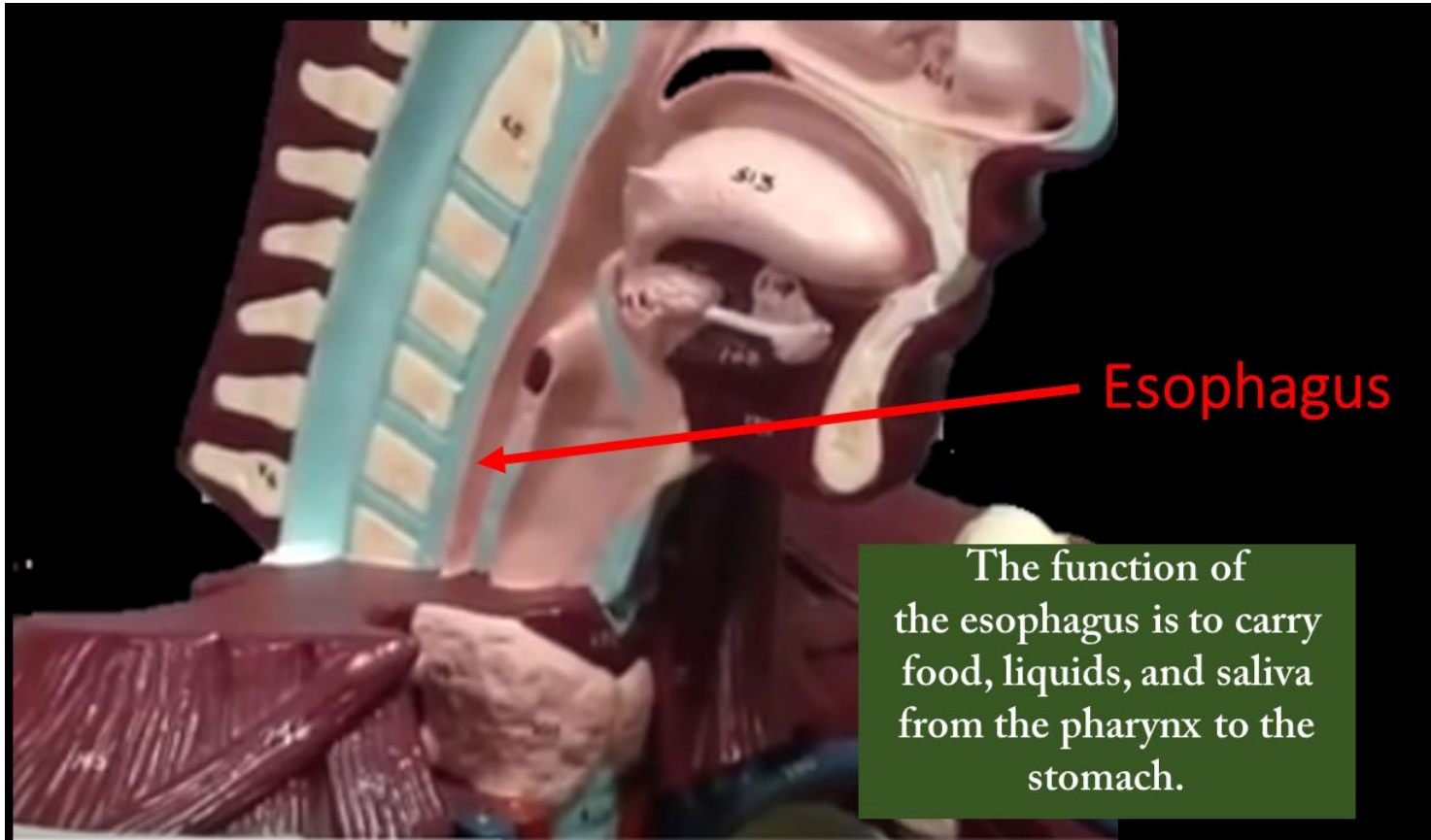
# Pharynx (Throat)

# Pharynx (Throat)

- The muscular walls of the pharynx function in the process of swallowing, which allows food to be delivered to the esophagus.
- It serves as a pathway for the movement of food from the mouth to the esophagus.
- When food is swallowed, it travels from the oral cavity to the oropharynx, then on to the laryngopharynx.
- The oropharynx and the laryngopharynx are common pathways for both food and air.
- The inferior portion of the pharynx diverges to form the esophagus (for food delivery) and the trachea (for air exchange).
- *The epiglottis regulates what substances enter the airway of the trachea.*



# THROAT

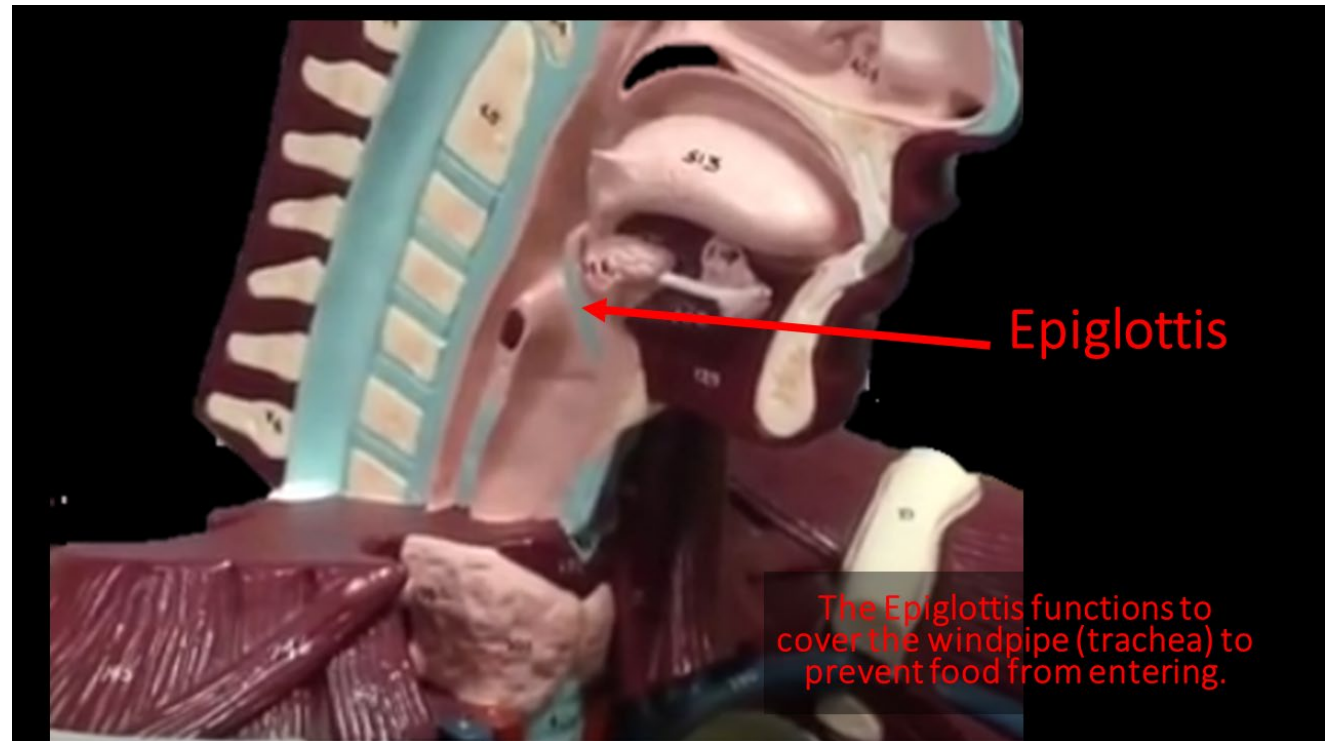


## The Esophagus

- The esophagus is lined with smooth muscle that propels swallowed food to the stomach.
- The esophagus begins as a continuation of the pharynx and travels downward through thoracic cavity, then through the diaphragm, to enter the abdominal cavity where it meets with the stomach.
- The function of the esophagus is deliver food from the pharynx to the stomach.

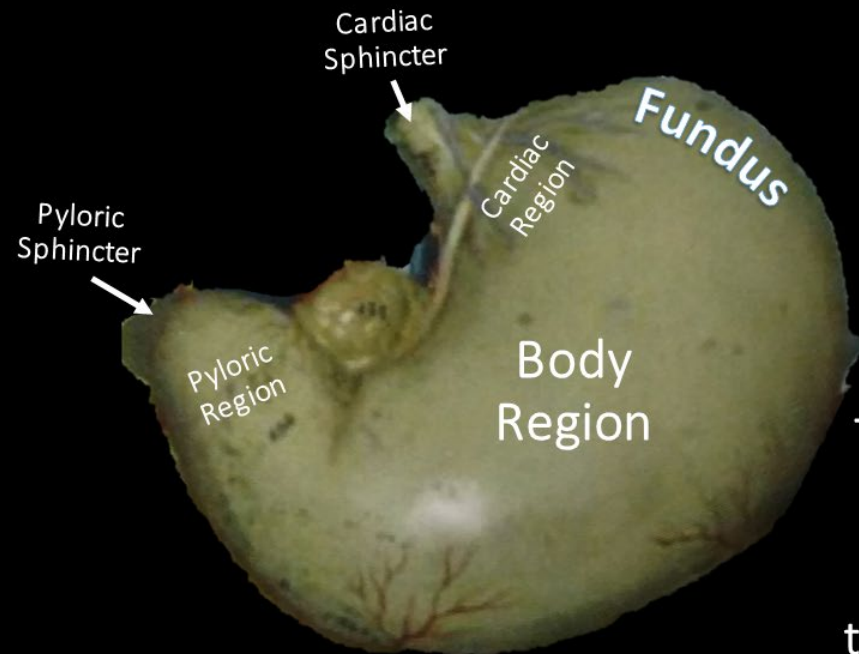
## *The epiglottis*

- Food goes down the esophagus and air goes down the trachea.
- **The epiglottis is a small flap of tissue that covers the trachea when you swallow to prevent food from entering the airways!**





# Anatomy of the Stomach Model



The function of the stomach is to secrete acid and digestive enzymes to break down food.

## The Stomach

- The stomach contains some main anatomical features.
- The stomach begins at the **cardiac sphincter** that connects the esophagus to the stomach.
- Food enters the first portion of the stomach, called the **cardial region**.
- The **fundus** of the stomach is the superior "dome-shaped" region of the stomach that lies just inferior of the diaphragm.

# Cardiac Sphincter

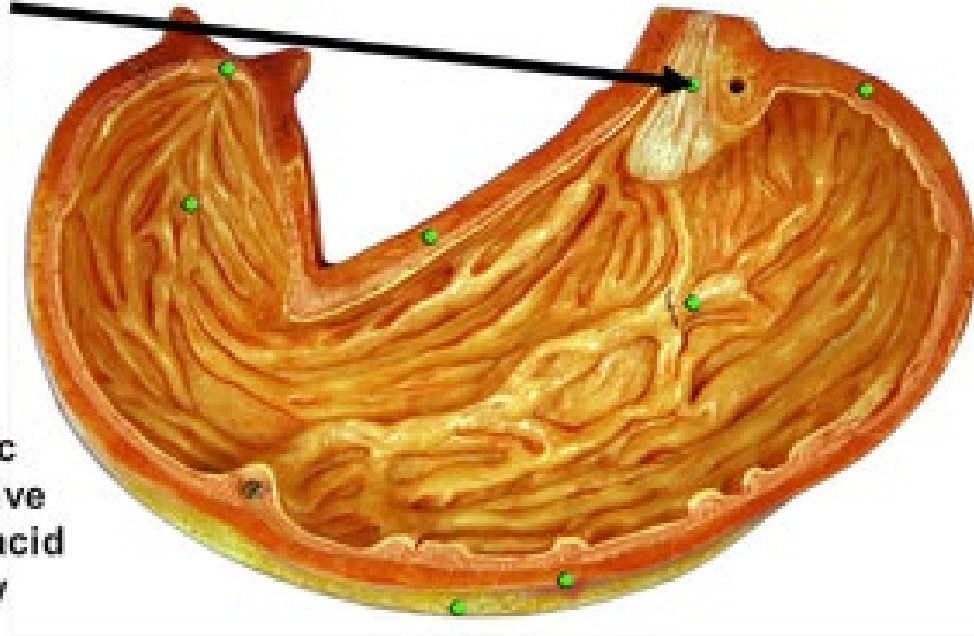


The function of the cardiac sphincter is to act as a valve that contracts to prevent acid reflux and relaxes to allow food to pass.

- From the esophagus, the bolus of food will pass through the cardiac sphincter of the stomach.

The Cardiac Sphincter

# Cardiac Sphincter



The function of the cardiac sphincter is to act as a valve that contracts to prevent acid reflux and relaxes to allow food to pass.

- The function of the cardiac sphincter is to act as a valve that relaxes to allow food to enter the stomach from the esophagus.
- The cardiac sphincter also functions to prevent stomach acid from traveling upward from the stomach into the esophagus.
- When the cardiac sphincter fails to prevent this from happening, the result is acid reflux or heart burn.

## The Cardiac Sphincter

## Pyloric Sphincter

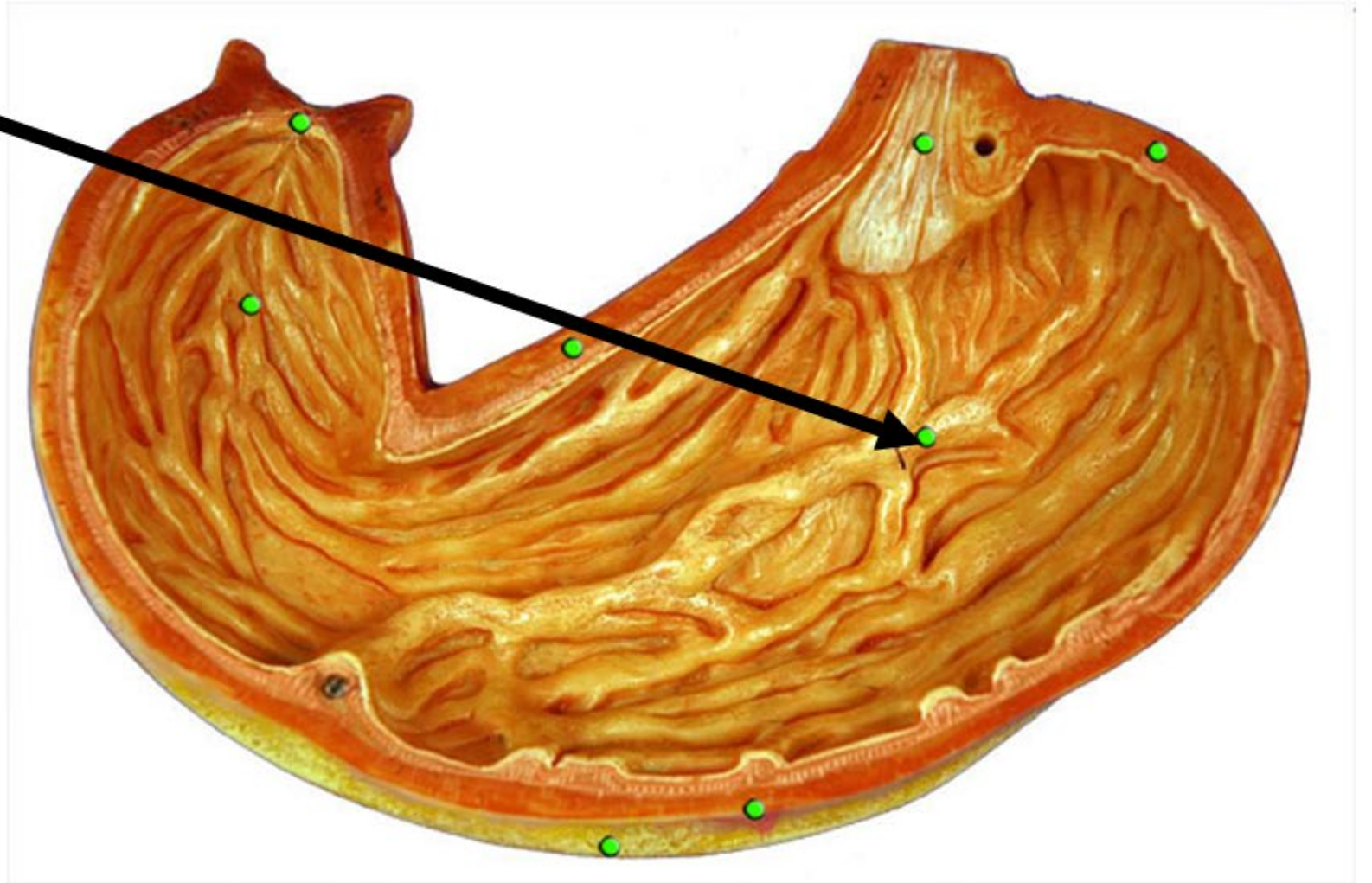


The function of the pyloric sphincter is to act as a valve to control the flow of partially digested food from the stomach to the small intestine.

- Partially digested food will pass from the stomach to the duodenum through the pyloric sphincter of the stomach.
- The function of the pyloric sphincter is to act as a valve that prevents larger chunks of food to pass onto the duodenum from the stomach.
- The pyloric valve only allows food that has been broken down into relatively small parts to pass onto the duodenum.
- The duodenum is considered the first part of the small intestine.

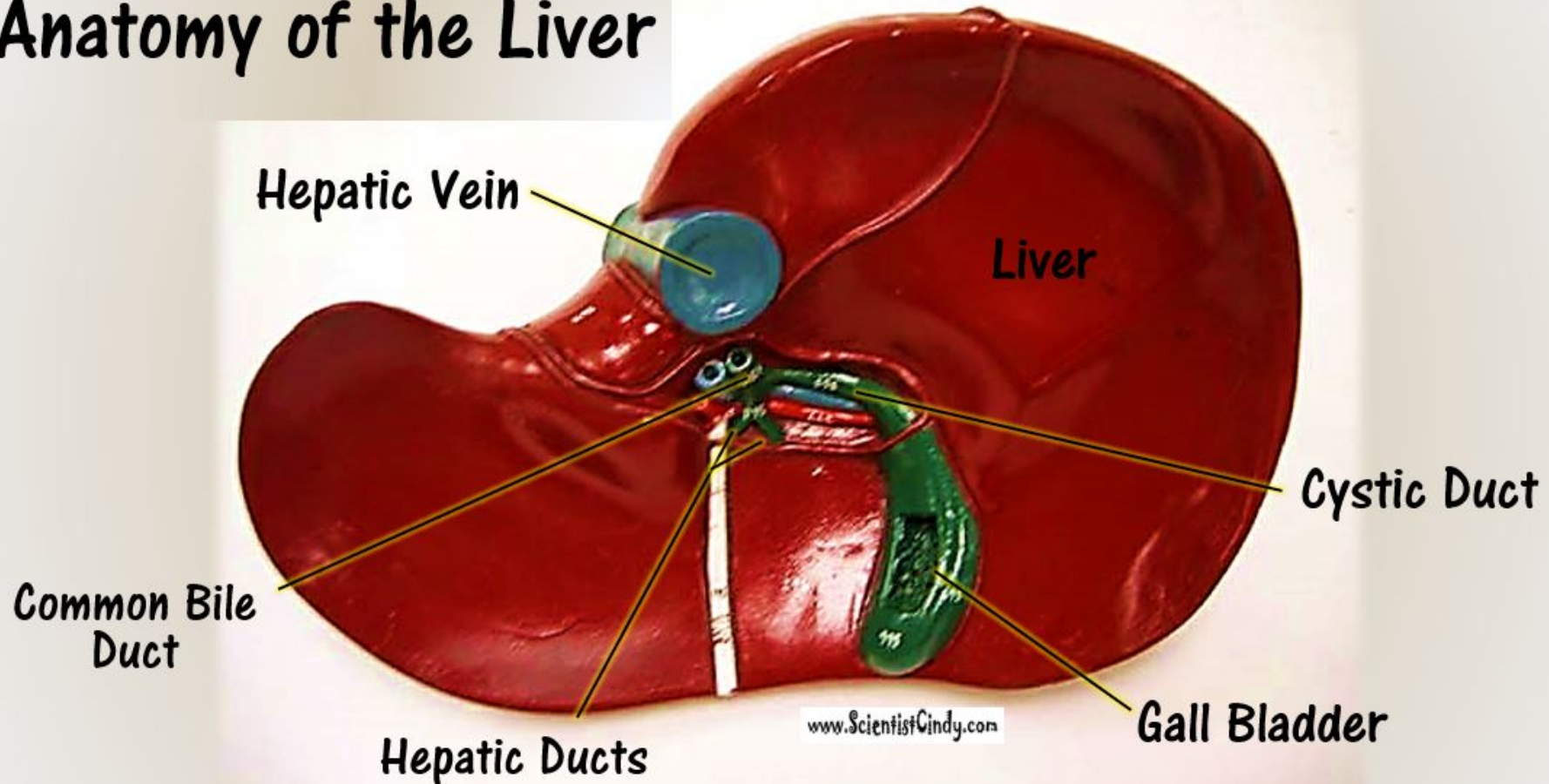
# THE PYLORIC SPHINCTER

Rugae  
*(large folds)*

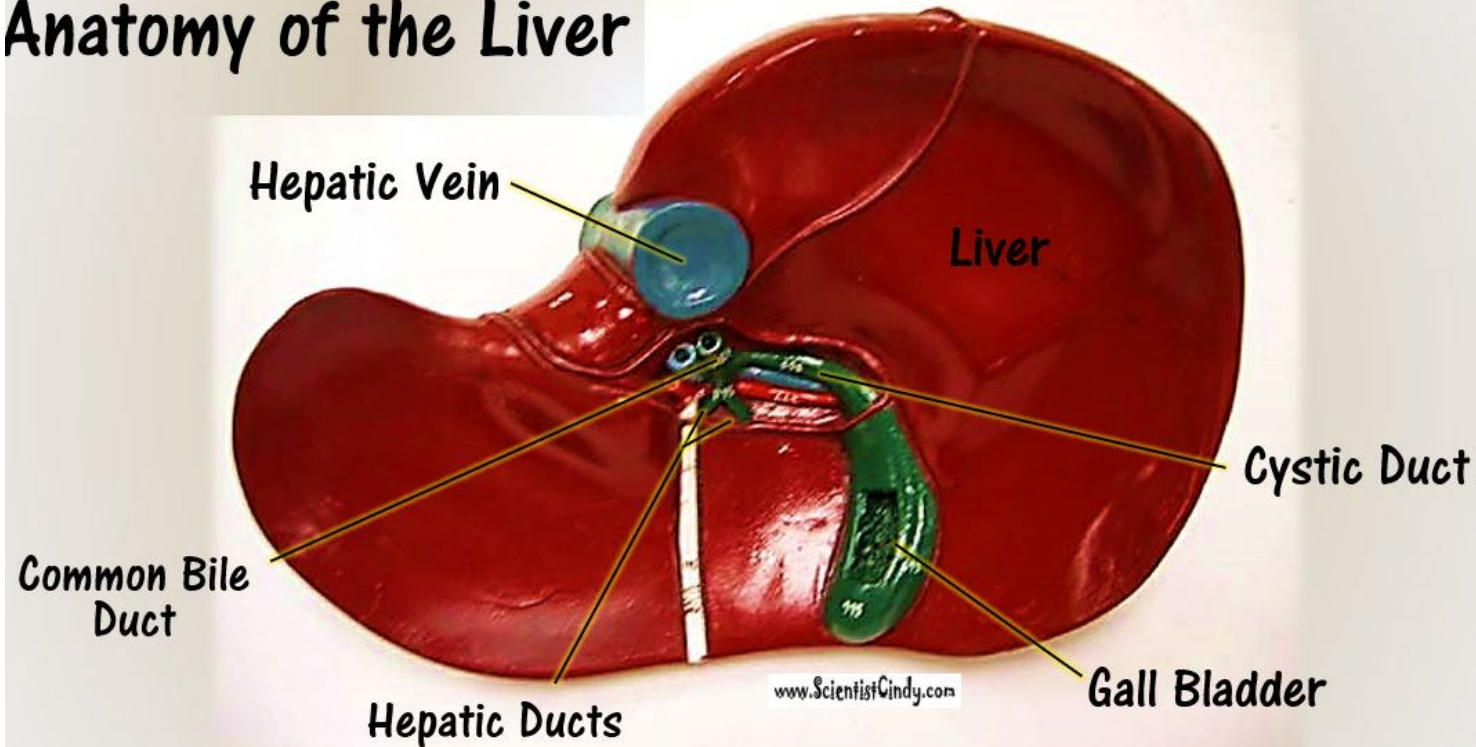


# The Liver and the Gallbladder

## Anatomy of the Liver



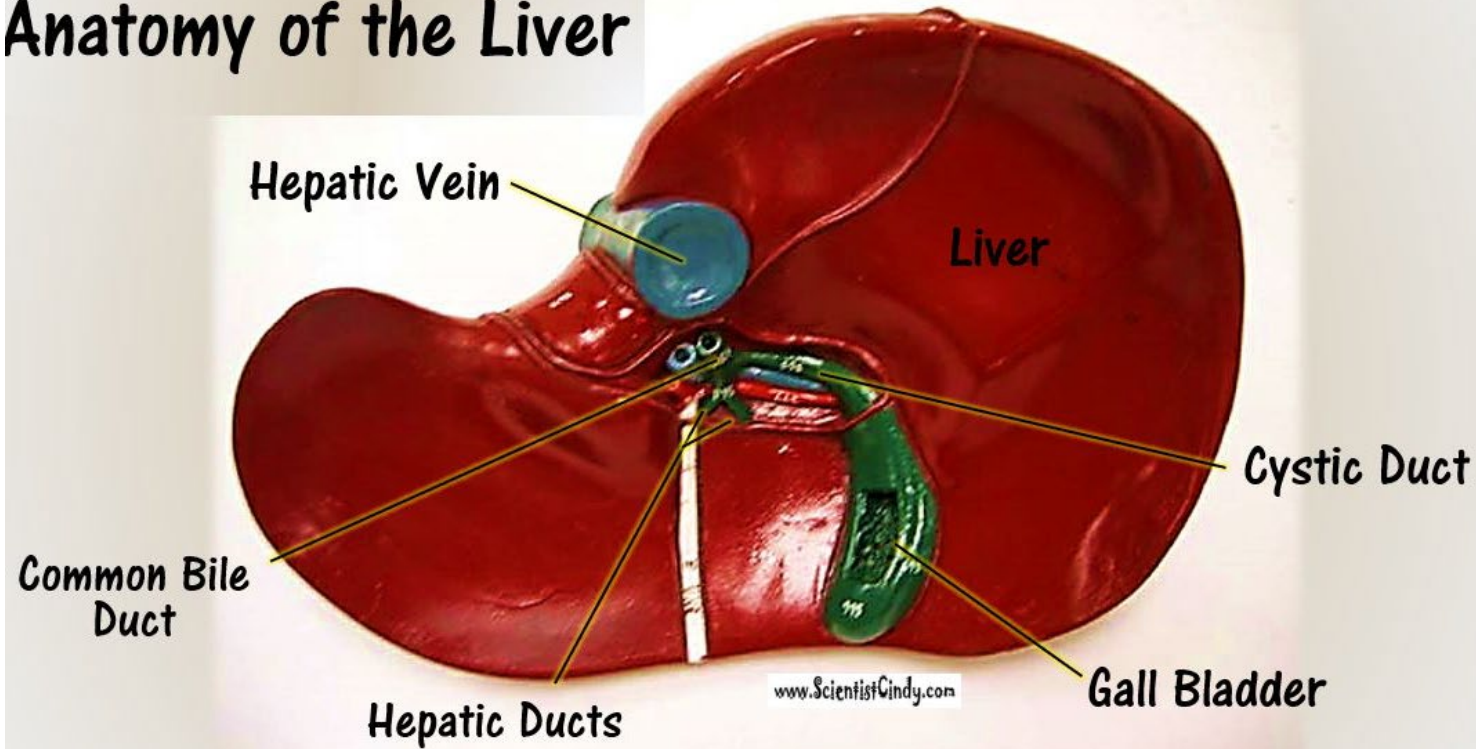
# Anatomy of the Liver



- The liver functions to detoxify chemicals, metabolize drugs, secrete the digestive enzymes in the form of bile, and produces blood clotting factors.
- In the digestive system, the liver functions to secrete the digestive enzymes in the form of bile which helps to break down fats (lipids).

## The Liver and the Gallbladder

# Anatomy of the Liver

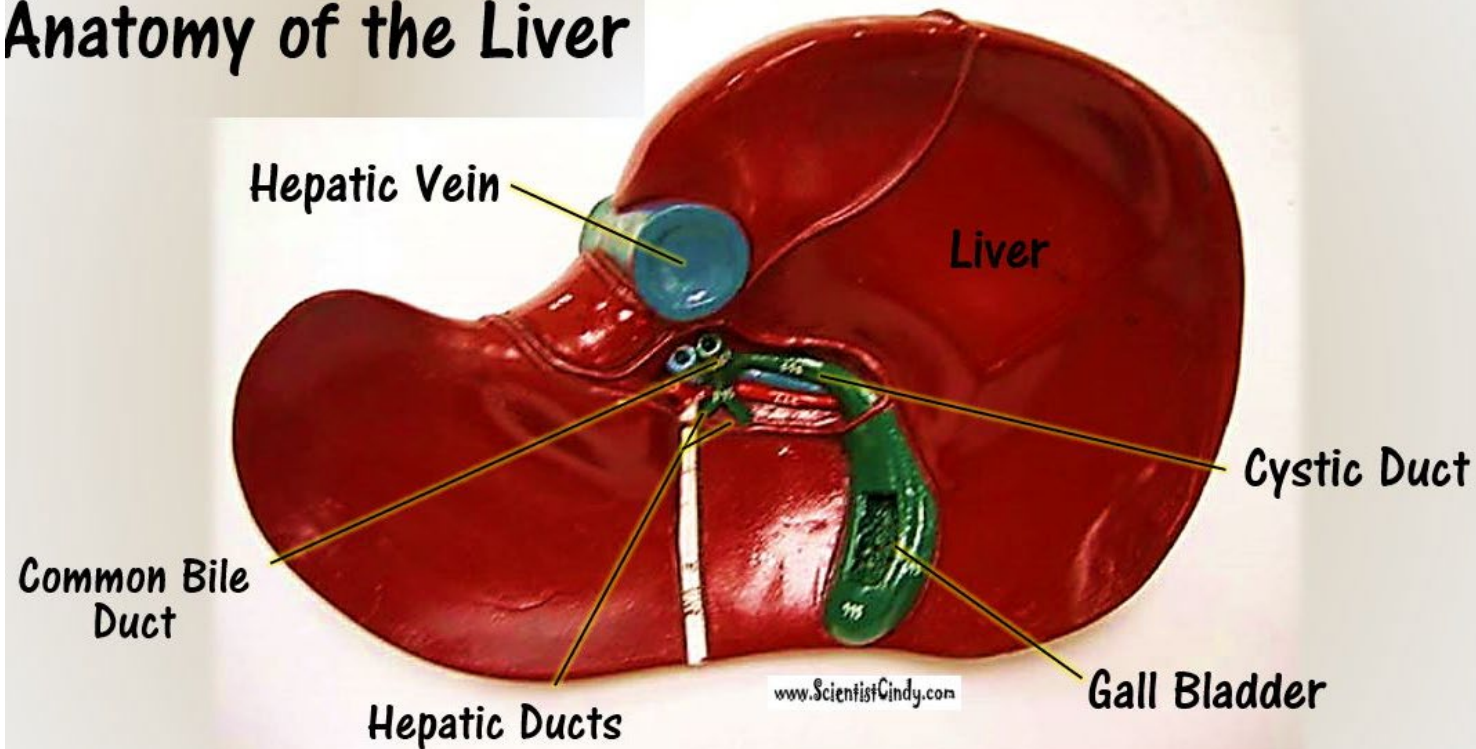


- The bile produced in the liver gets stored in the gallbladder which lies directly underneath the liver.
- The gallbladder's function is to store and concentrate the bile that was made in the liver. Bile can also bypass the gallbladder altogether and get secreted by a different pathway.

## The Gallbladder



# Anatomy of the Liver



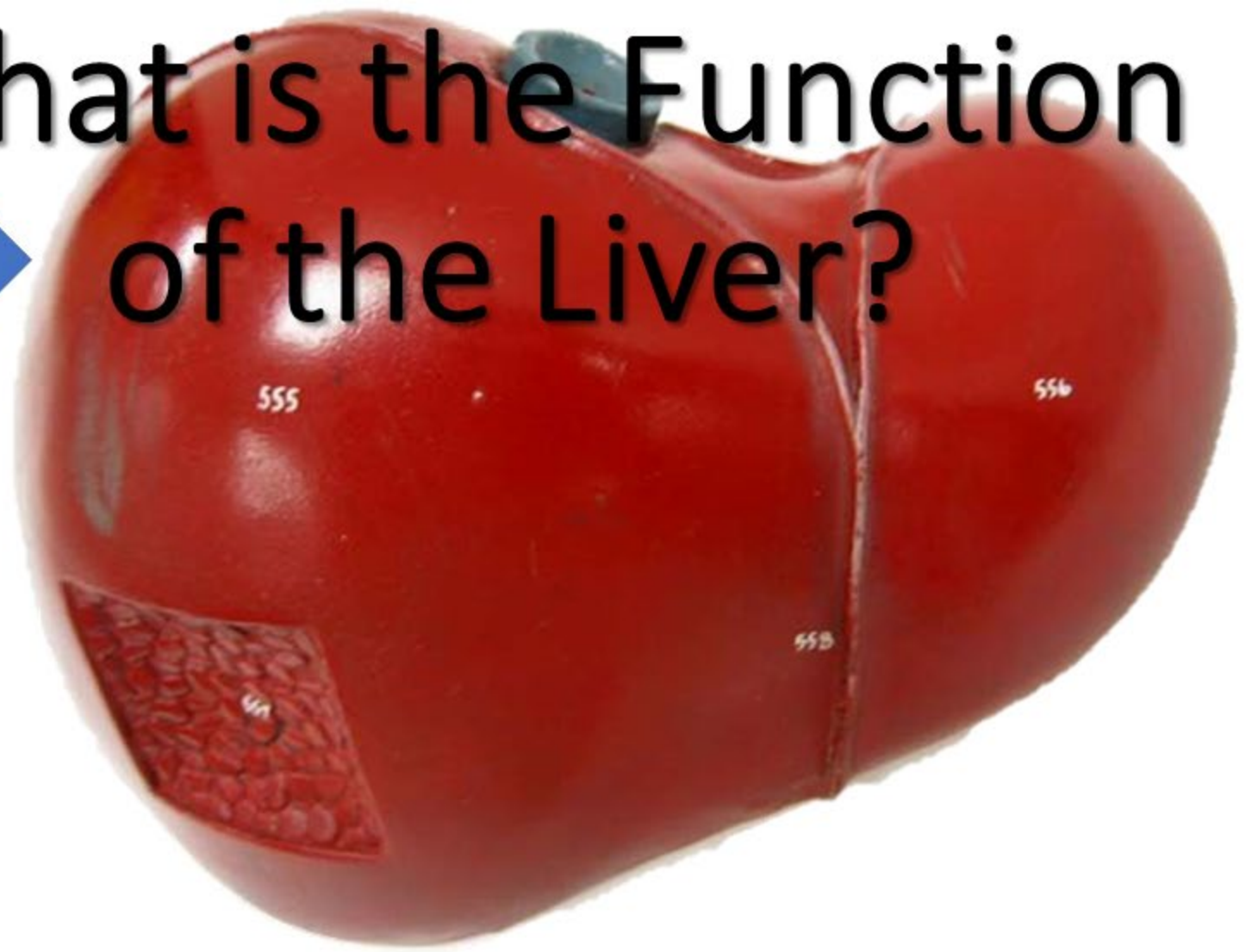
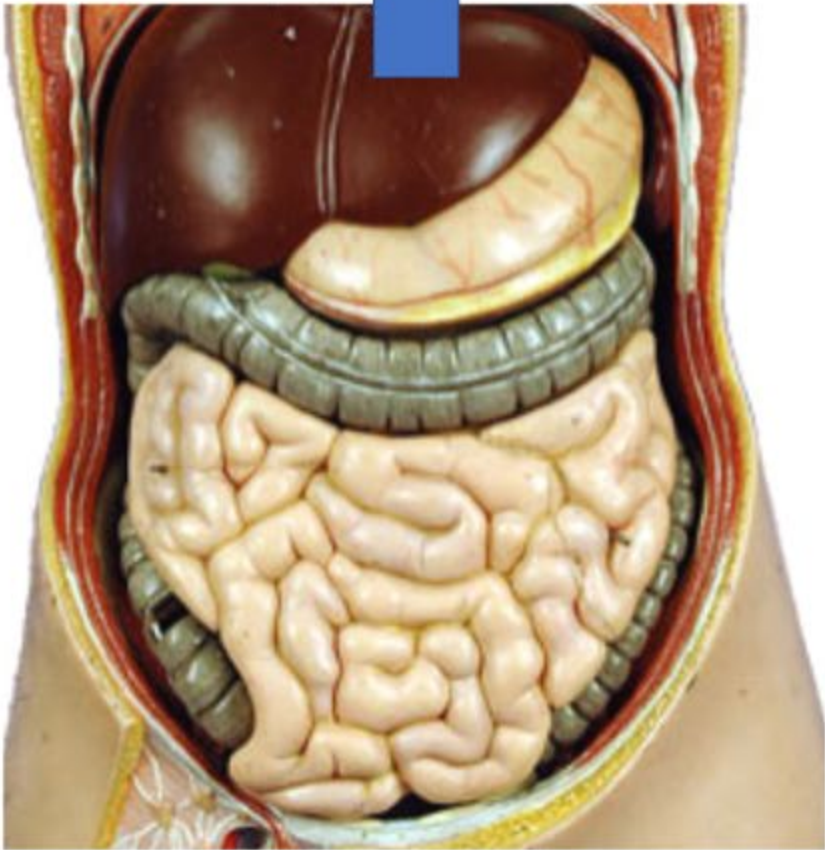
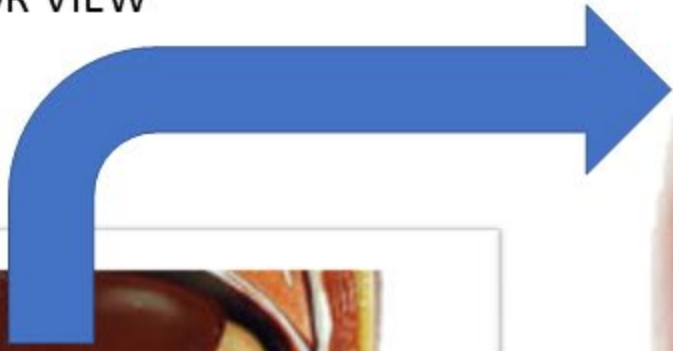
The destination of the bile is the duodenum of the small intestine.

- Bile coming from the gallbladder will leave the gallbladder through the cystic duct, then travel through the common bile duct to reach the duodenum.
- Bile coming from the liver directly, will travel through the hepatic ducts, then the common bile duct, and will end up at the duodenum.
- Therefore, the cystic duct and the hepatic duct come together to form the common bile duct.

## The Ducts

# What is the Function of the Liver?

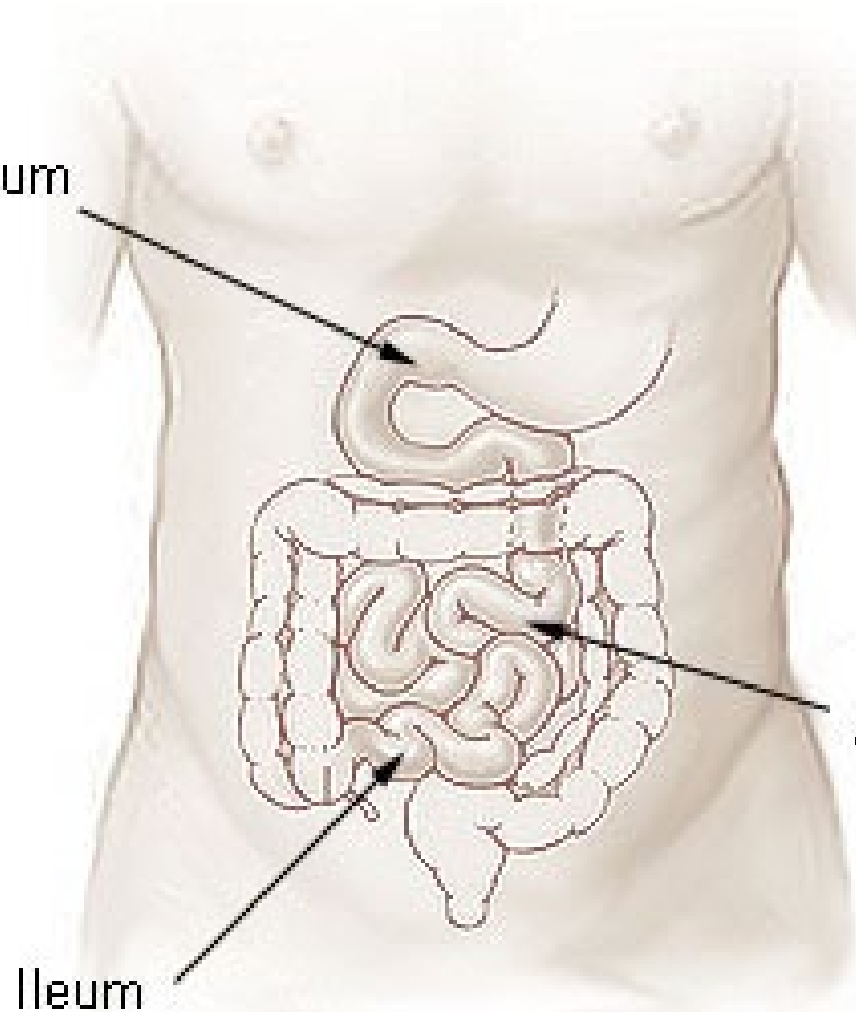
• SUPERIOR VIEW



# The Small Intestines

- The small intestine is the longest part of the alimentary canal. **It functions to digest food (chyme) and absorb its nutrients. The small intestine is the part of the intestine is where 90% of the digestion and absorption of food occurs.** Digestive enzymes made by the pancreas travel to the duodenum of the small intestine. The small intestines are also lined with smooth muscle that contracts and relaxes to assist digestion and absorption and to move food through the 3 to 5 meters of small intestine you have in your body. This process takes 3 to 6 hours.

Duodenum



Jejunum

Ileum

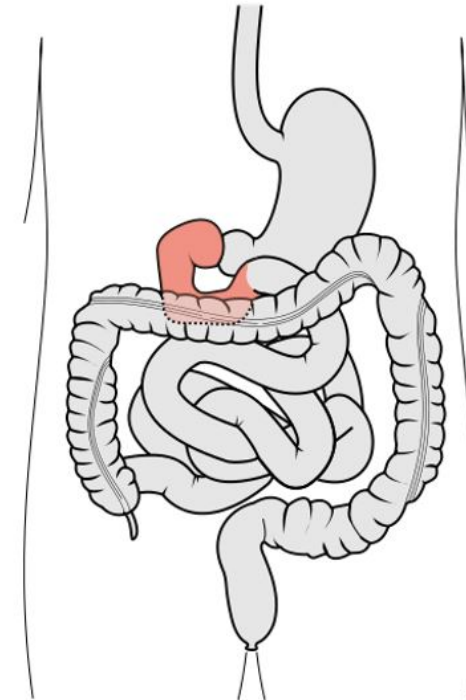
The small intestine begins at the pyloric sphincter of the stomach and is divided into three sections:

The **duodenum**  
The **jejunum**  
The **ileum**.

# The Duodenum

- The stomach transforms your food into a paste-like, partially digested substance called *chyme*.
- The chyme leaves the stomach via the pyloric valve, and enters the duodenum which is the first part of the small intestine.
- The duodenum is the smallest portion of the small intestine.

## The Duodenum

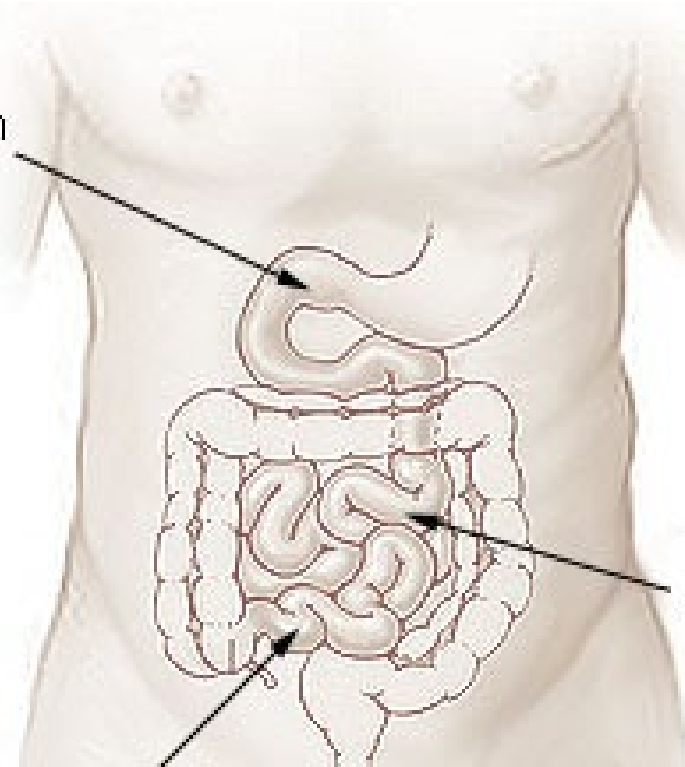


By Olek Remesz (wiki-pl: Orem, commons: Orem) - Own work, CC BY-SA 2.5-2.0-1.0, <https://commons.wikimedia.org/w/index.php?curid=2599148>

## The Jejunum

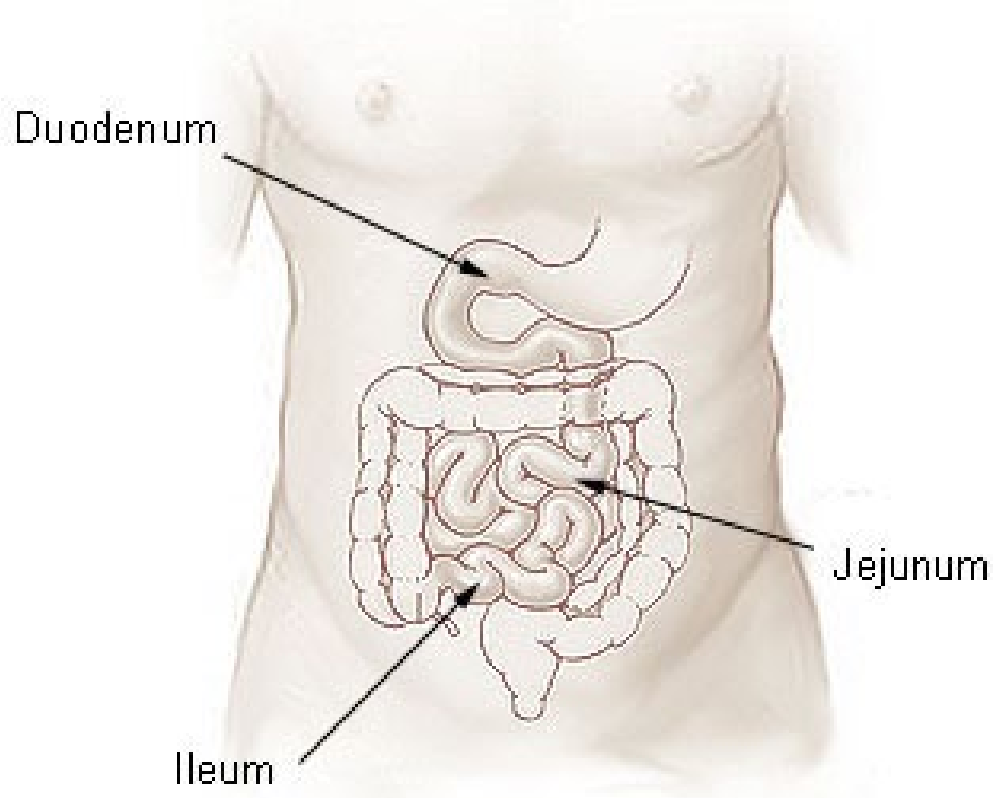
- The **jejunum** is the segment of the small intestine that comes after the duodenum.
- Most of the nutrients present in food are absorbed by the jejunum before being passed on to the ileum for further absorption.

Duodenum



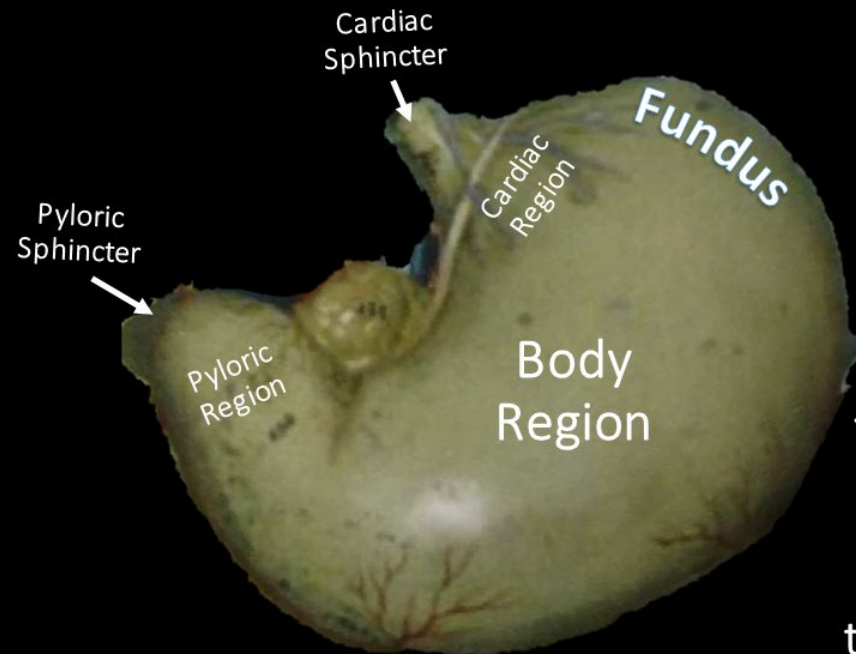
Jejunum

# The Ileum



- The **ileum** is the last part of the three part tube that makes up the small intestine.
- It is where the remaining nutrients are absorbed before moving into the large intestine.

# Anatomy of the Stomach Model



The function of the stomach is to secrete acid and digestive enzymes to break down food.

## The Stomach

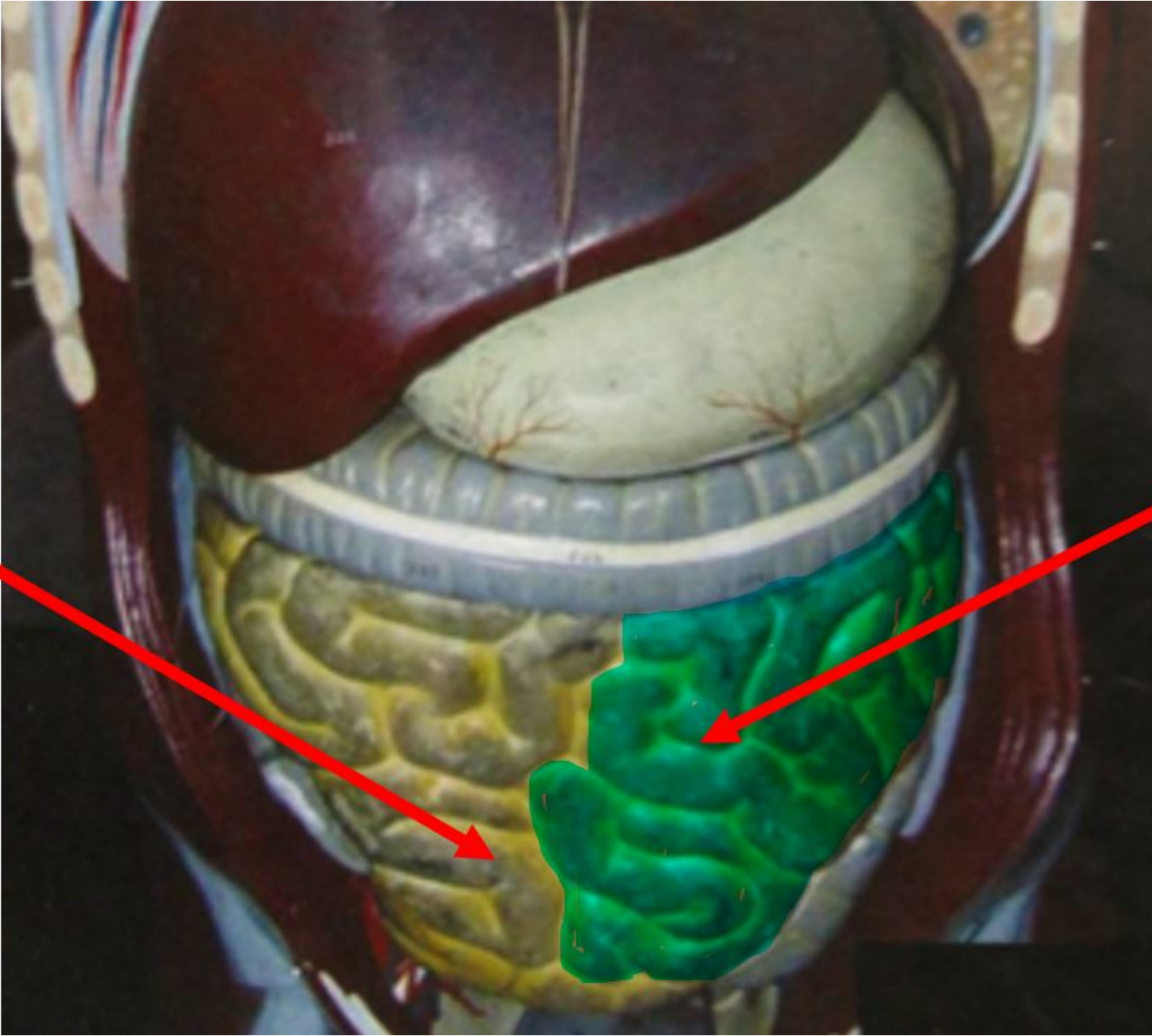
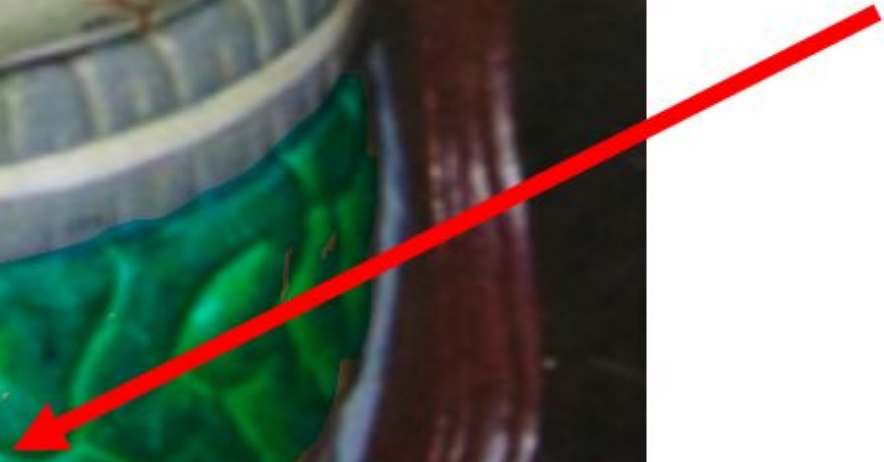
- The large midportion of the stomach is called **the body**.
- As you travel downward through the stomach, the body becomes the **pyloric region** (which includes the pyloric antrum and pyloric canal) which looks like a funnel.
- The terminal end of the stomach contains the **pyloric sphincter**.
- The word pylorus means “gatekeeper”.
- Living up to its name, the pyloric sphincter controls the entry of partially digested food into the small intestine.



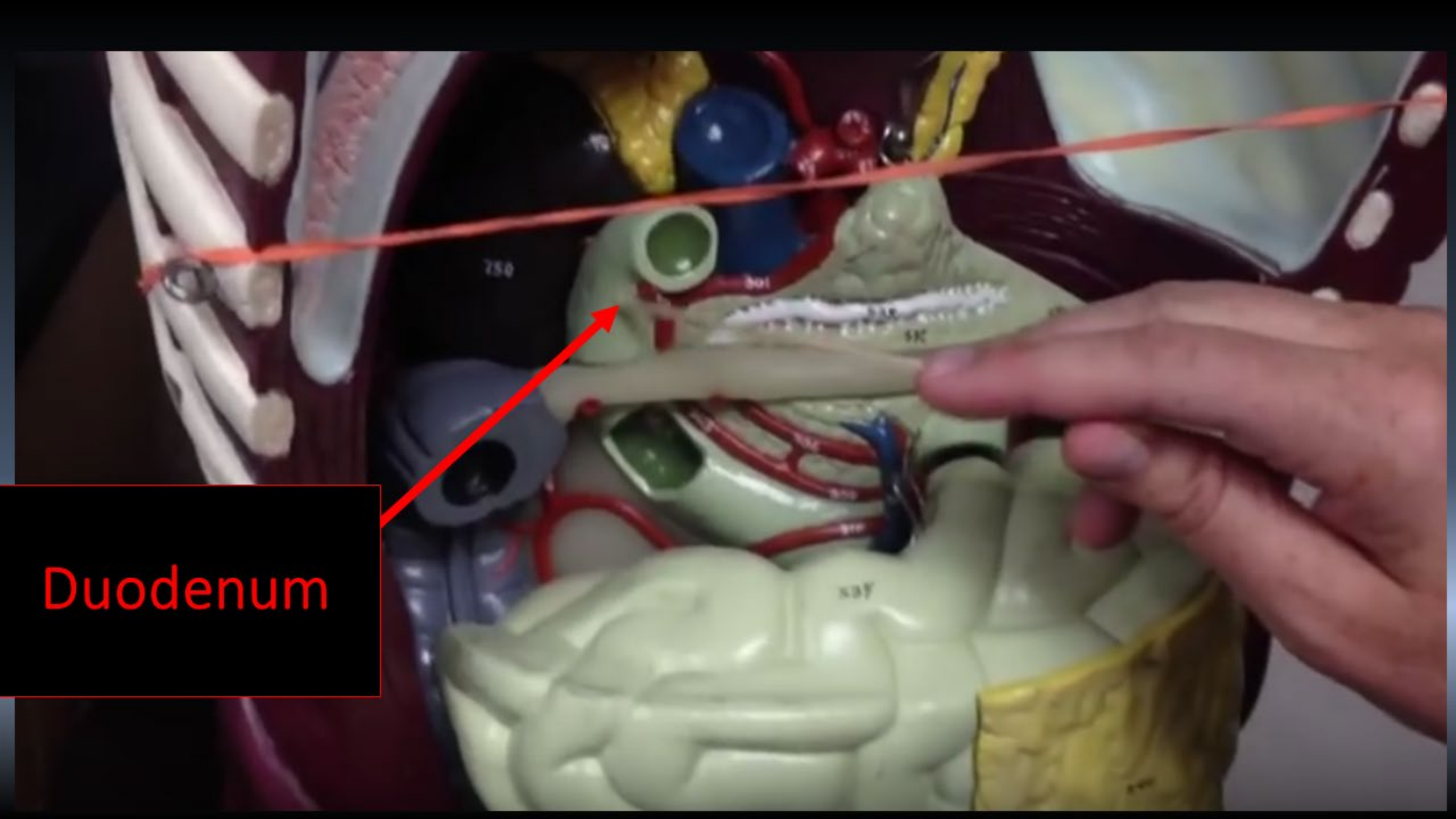
Ileum



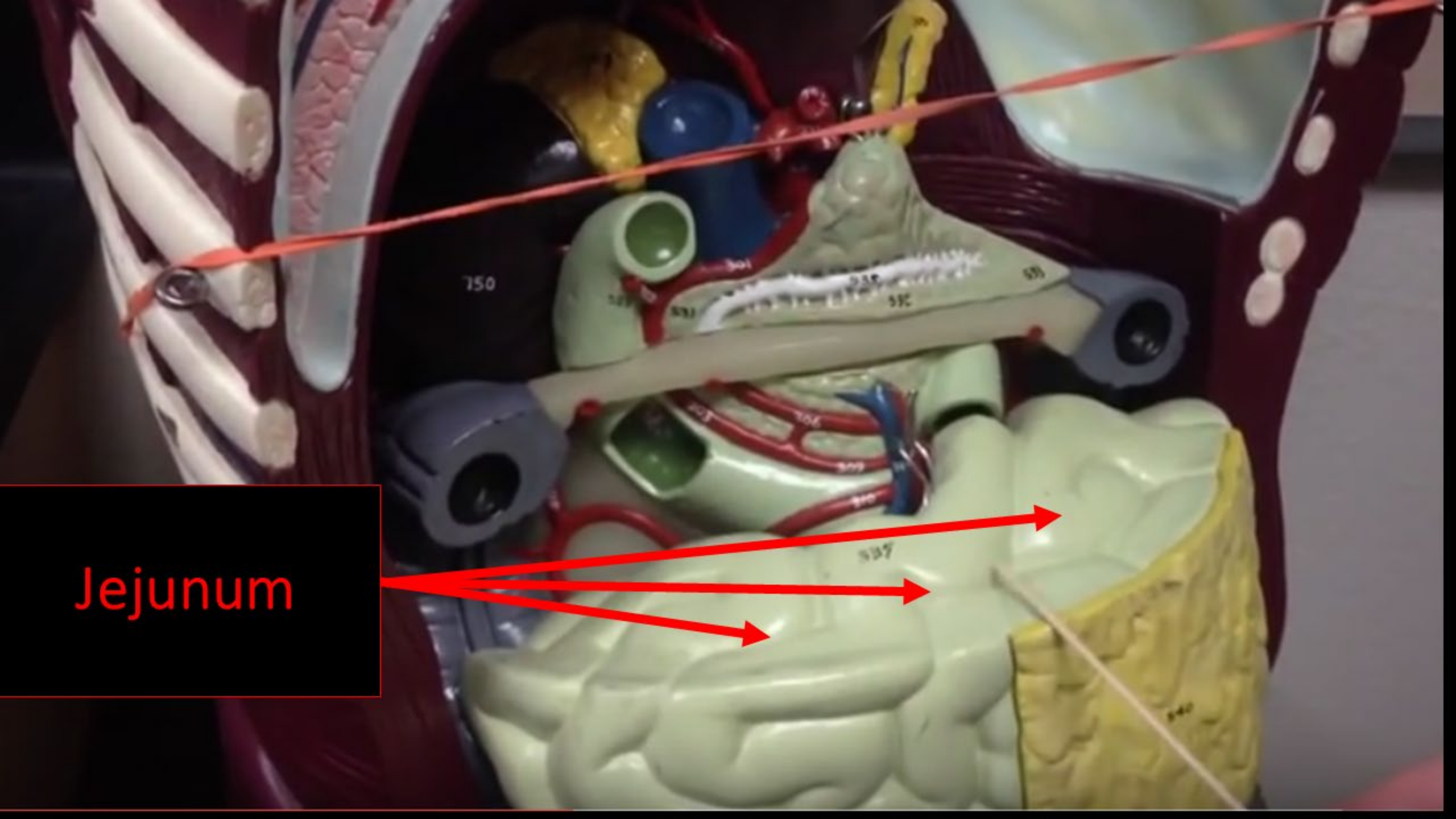
Jejunum



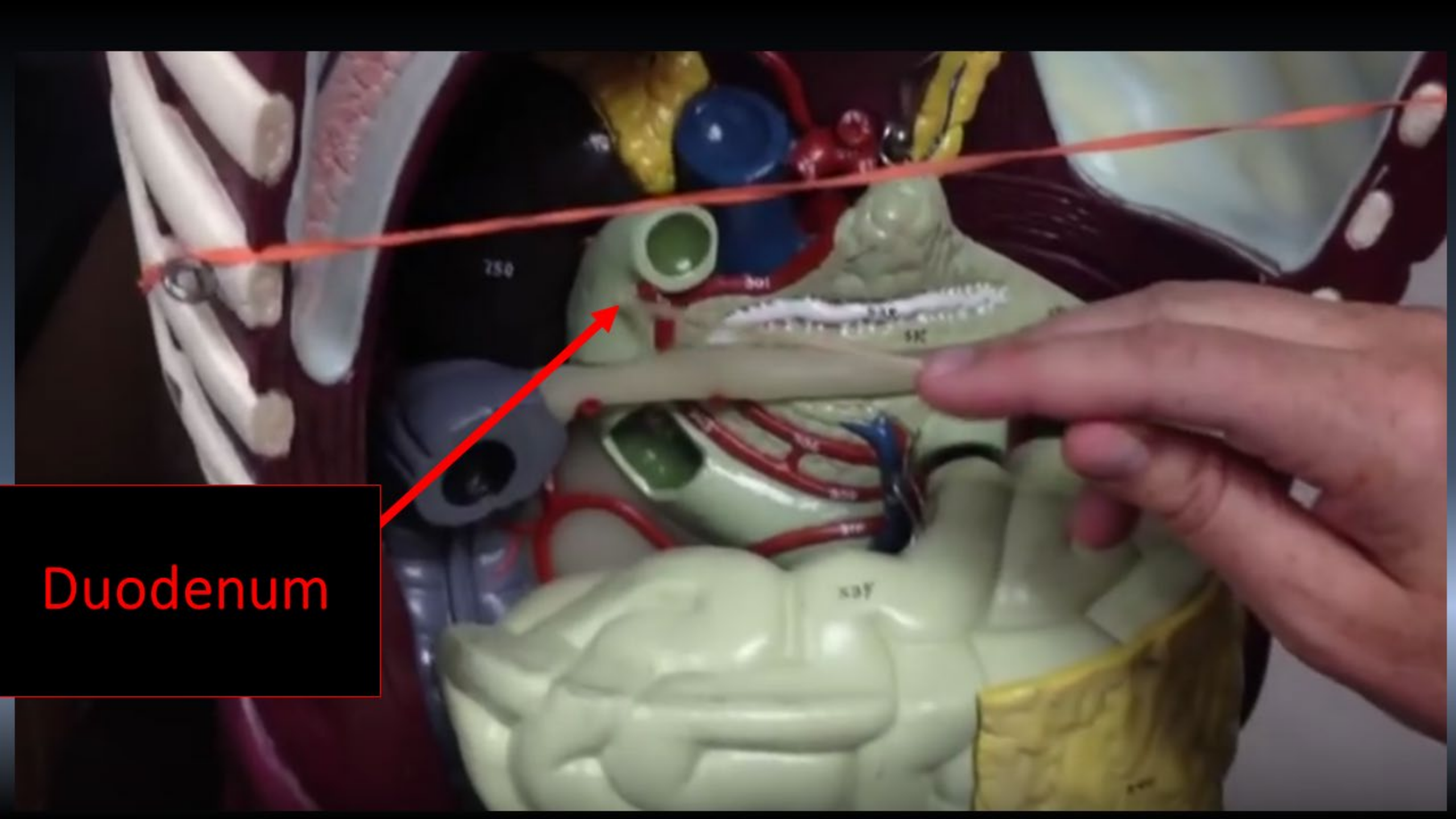
Duodenum



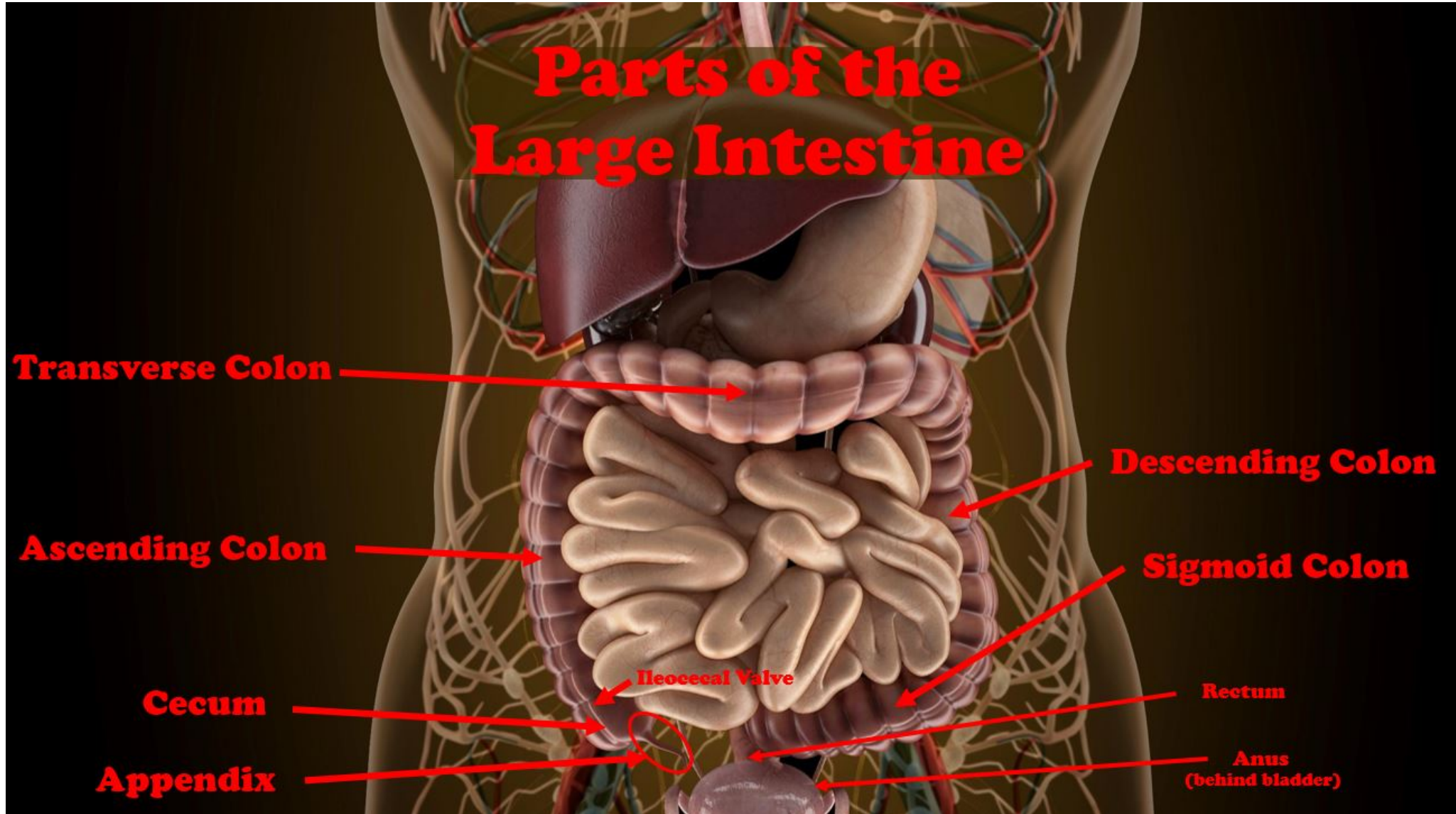
Jejunum



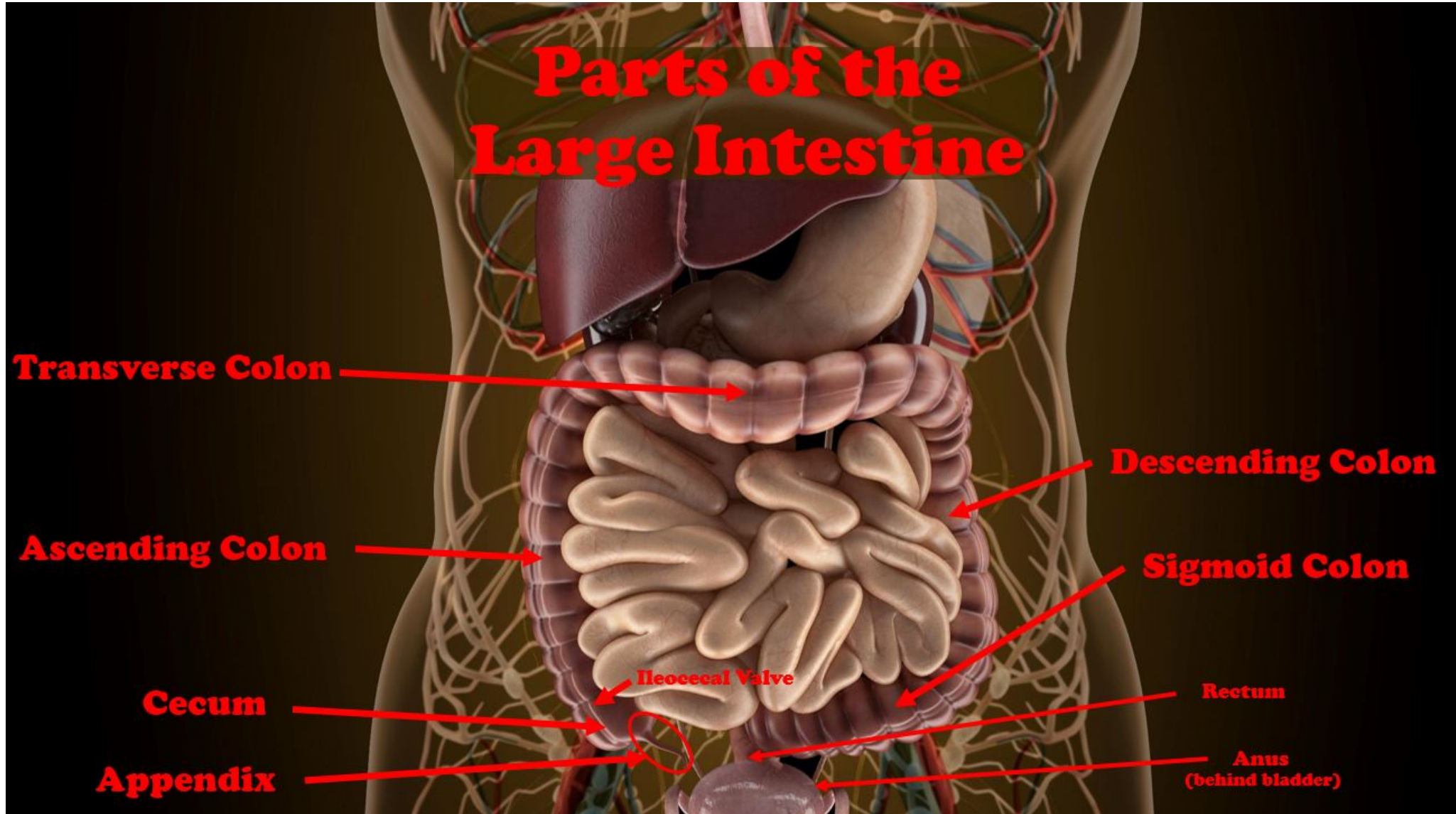
Duodenum



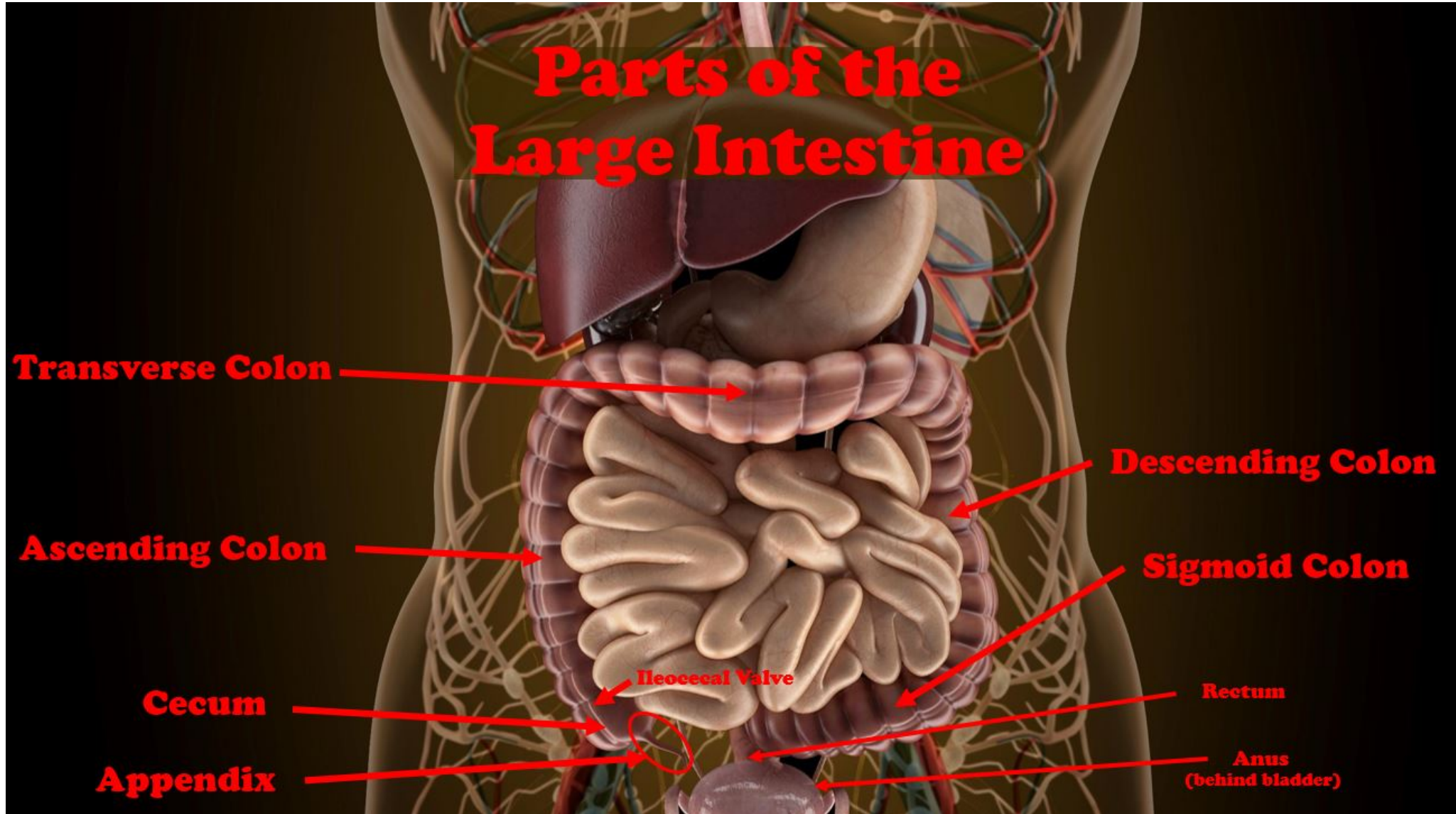
# Large Intestine

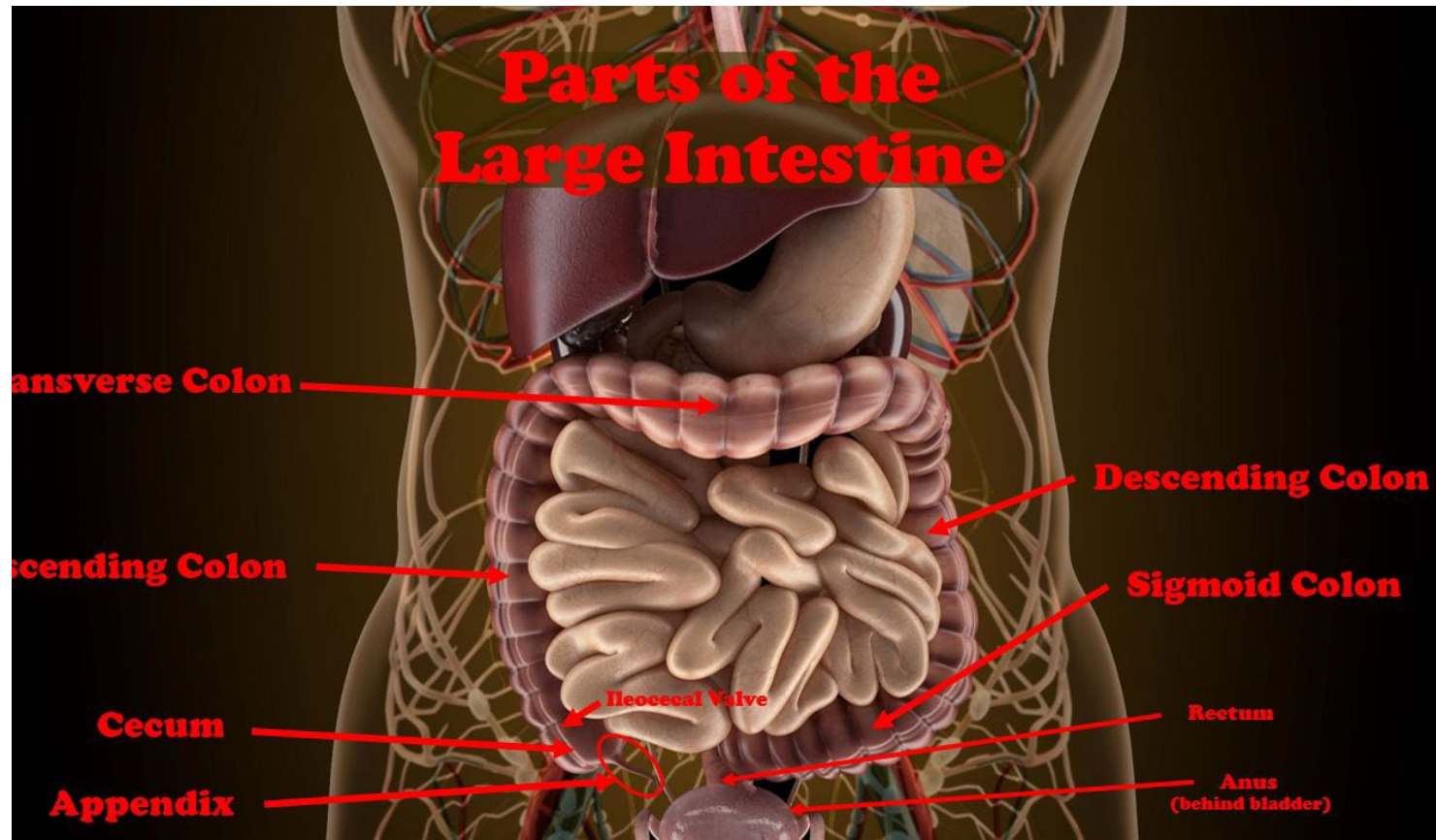


# Large Intestine



# Large Intestine





- The large intestine is separated into the following areas: Cecum
- Ascending Colon
- Transverse Colon
- Descending Colon
- Sigmoid Colon
- Rectum
- Anal Cana

Large Intestine

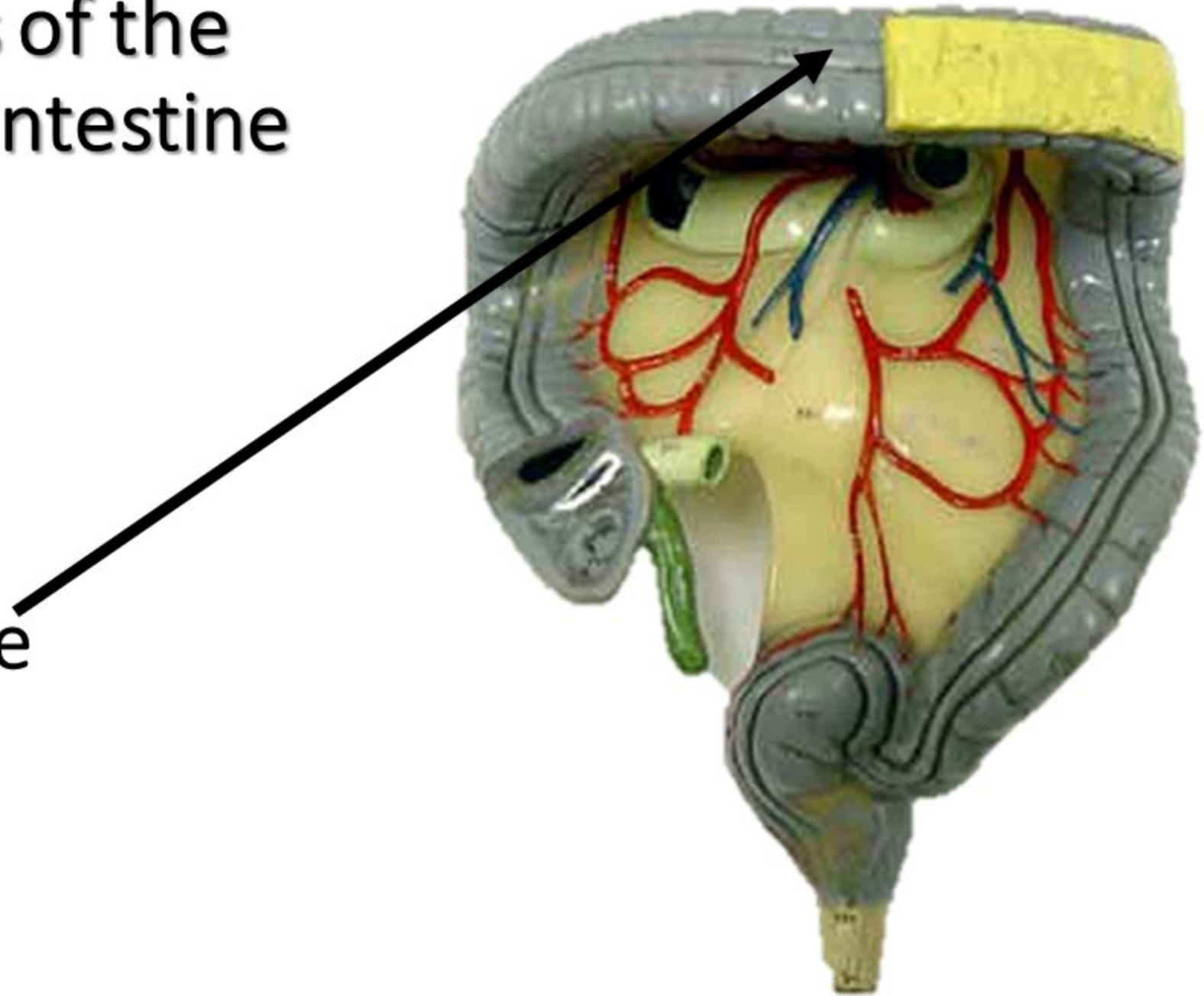


# The large intestine

- **The large intestine is the terminal portion of the alimentary canal (commonly known as the gastrointestinal tract).**
- **The large intestine function to absorb water and vitamins while converting undigested food into feces.**
- **The large intestine borders the small intestine and can be up to 5 feet long.**

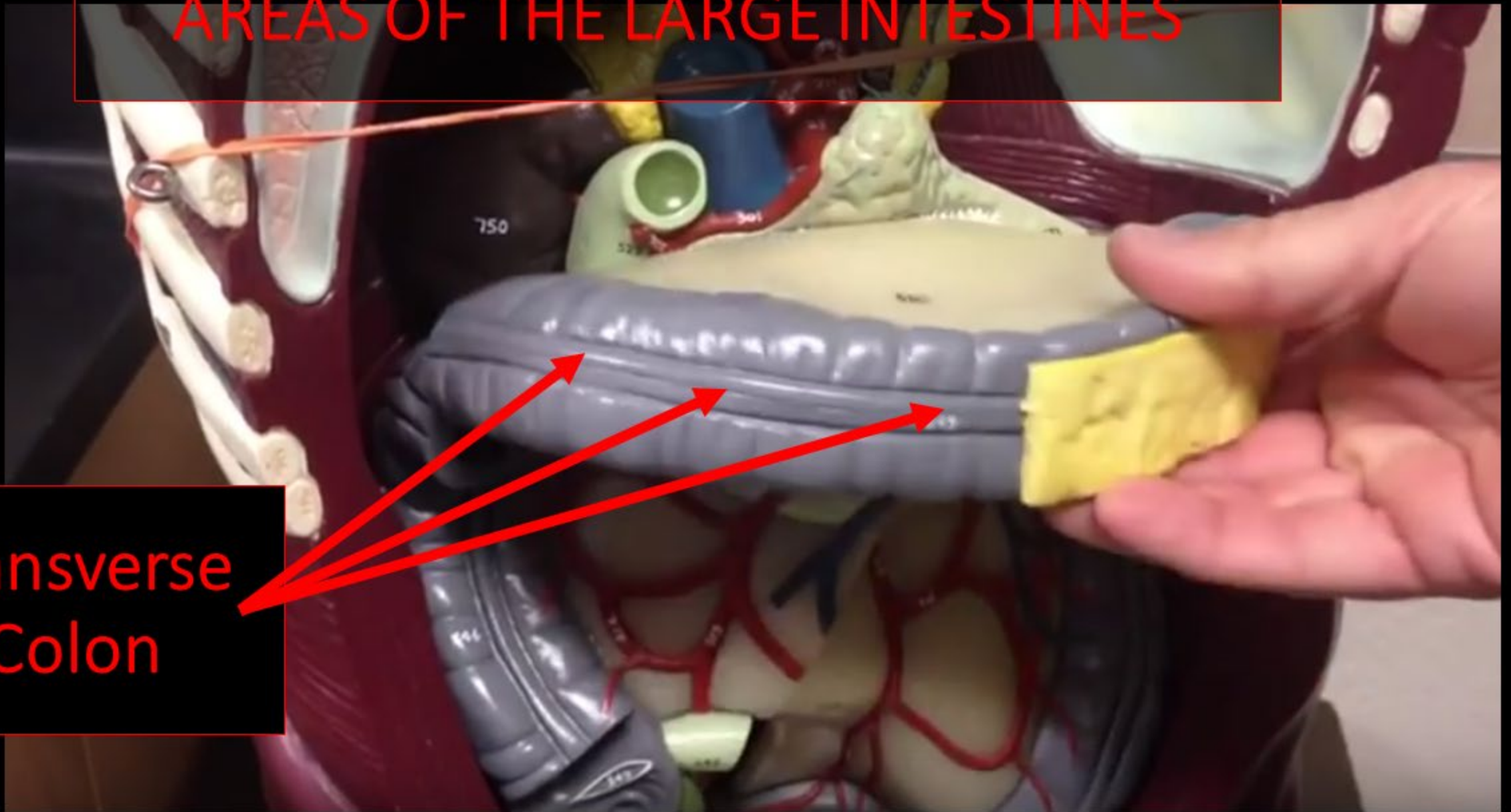
# Parts of the Large Intestine

Transverse Colon



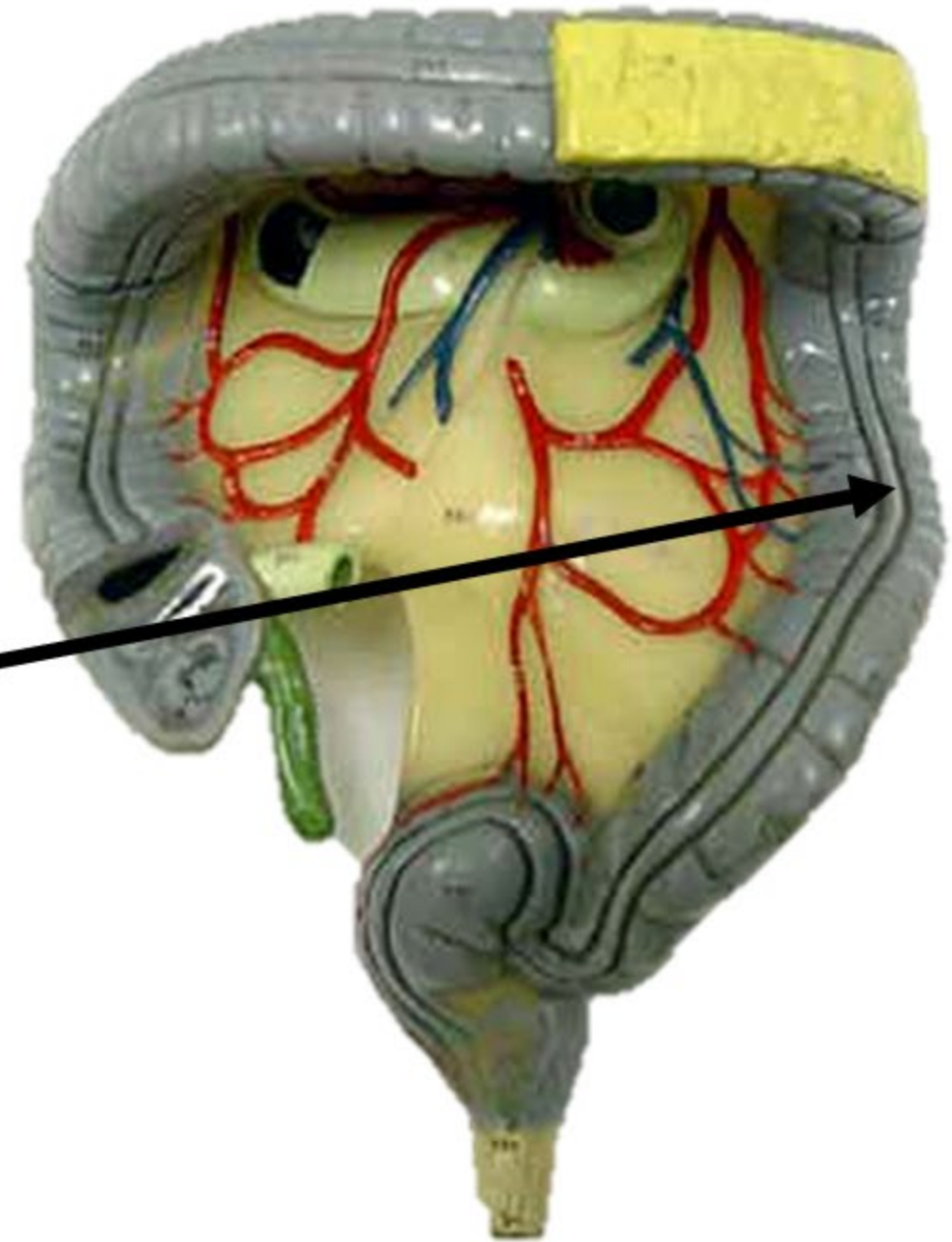
# AREAS OF THE LARGE INTESTINES

Transverse  
Colon



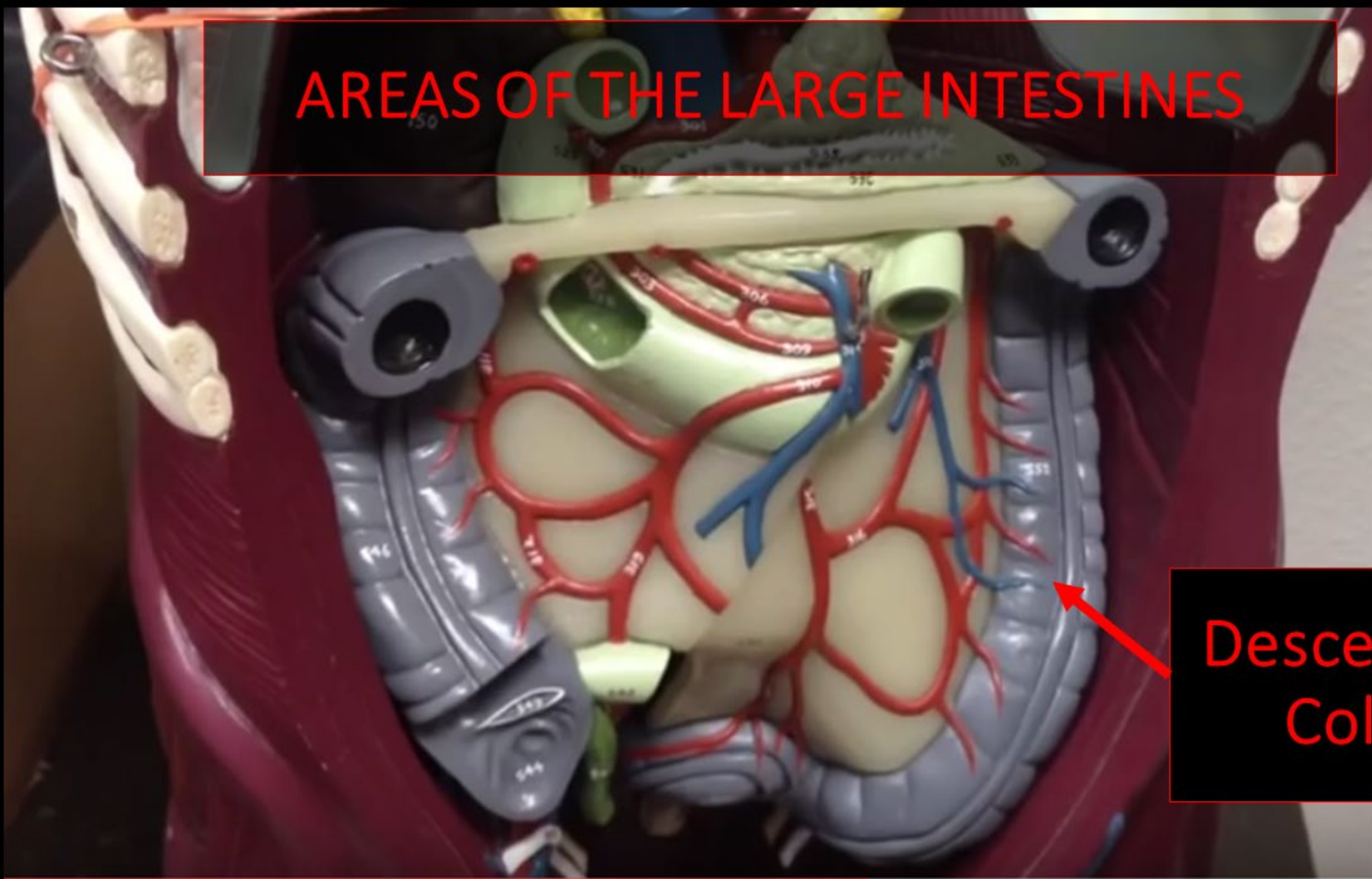
# Parts of the Large Intestine

Descending  
Colon



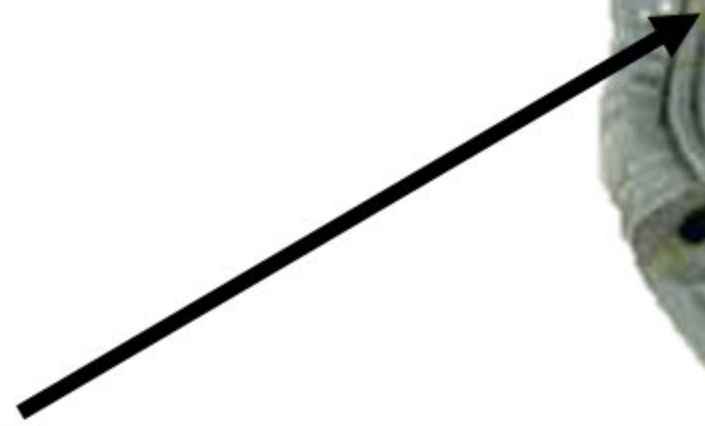
# AREAS OF THE LARGE INTESTINES

Descending  
Colon



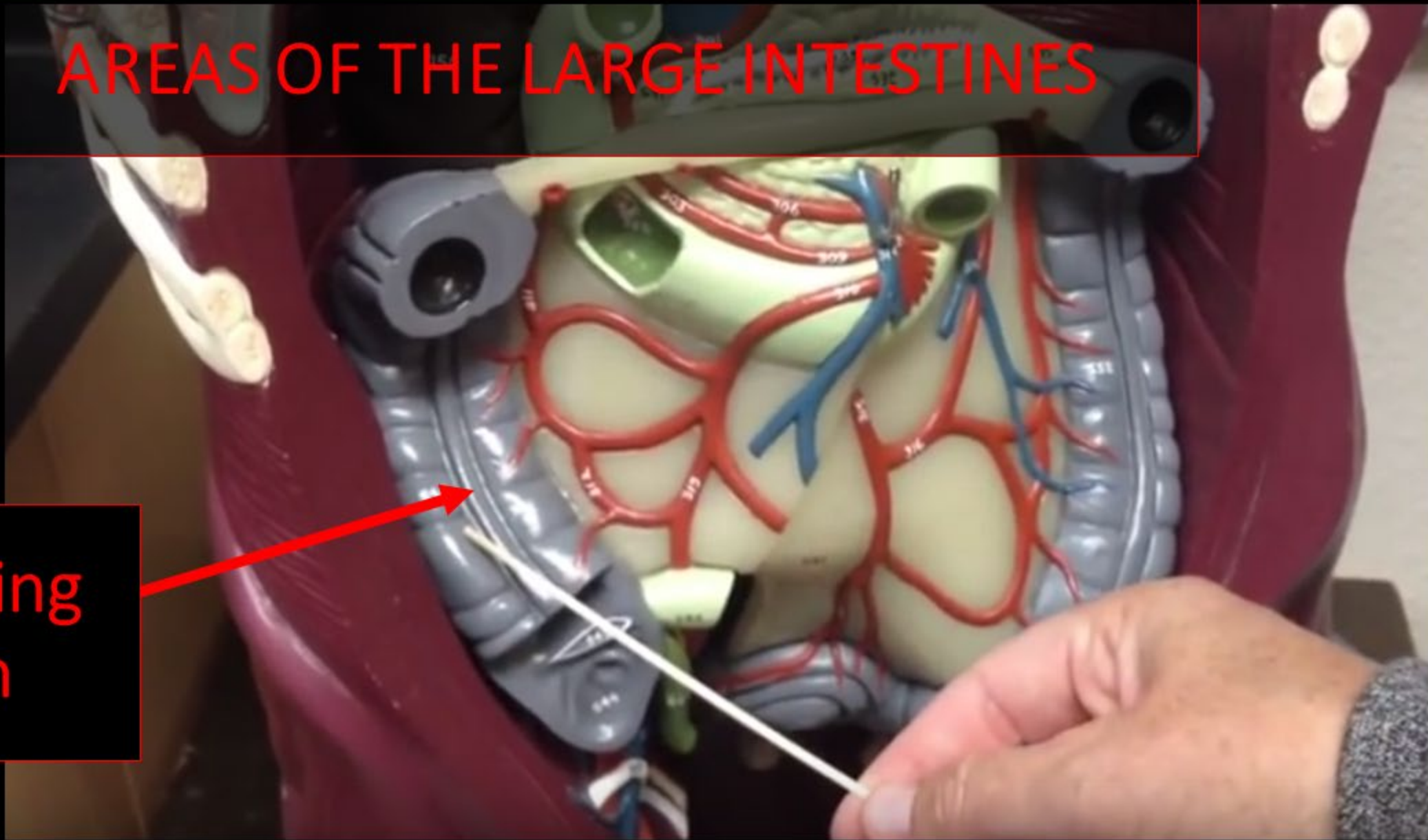
# Parts of the Large Intestine

Ascending  
Colon

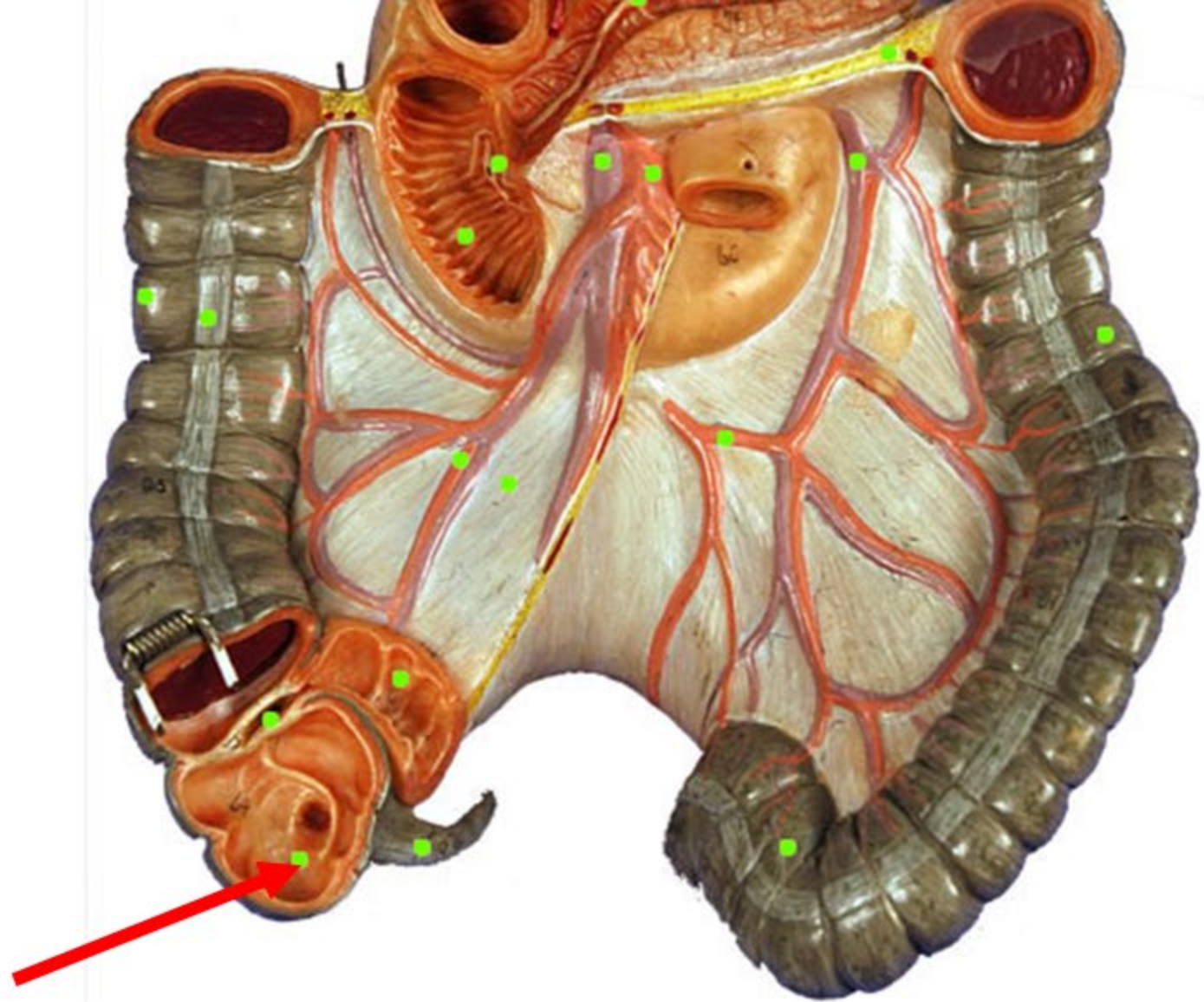


# AREAS OF THE LARGE INTESTINES

Ascending  
Colon

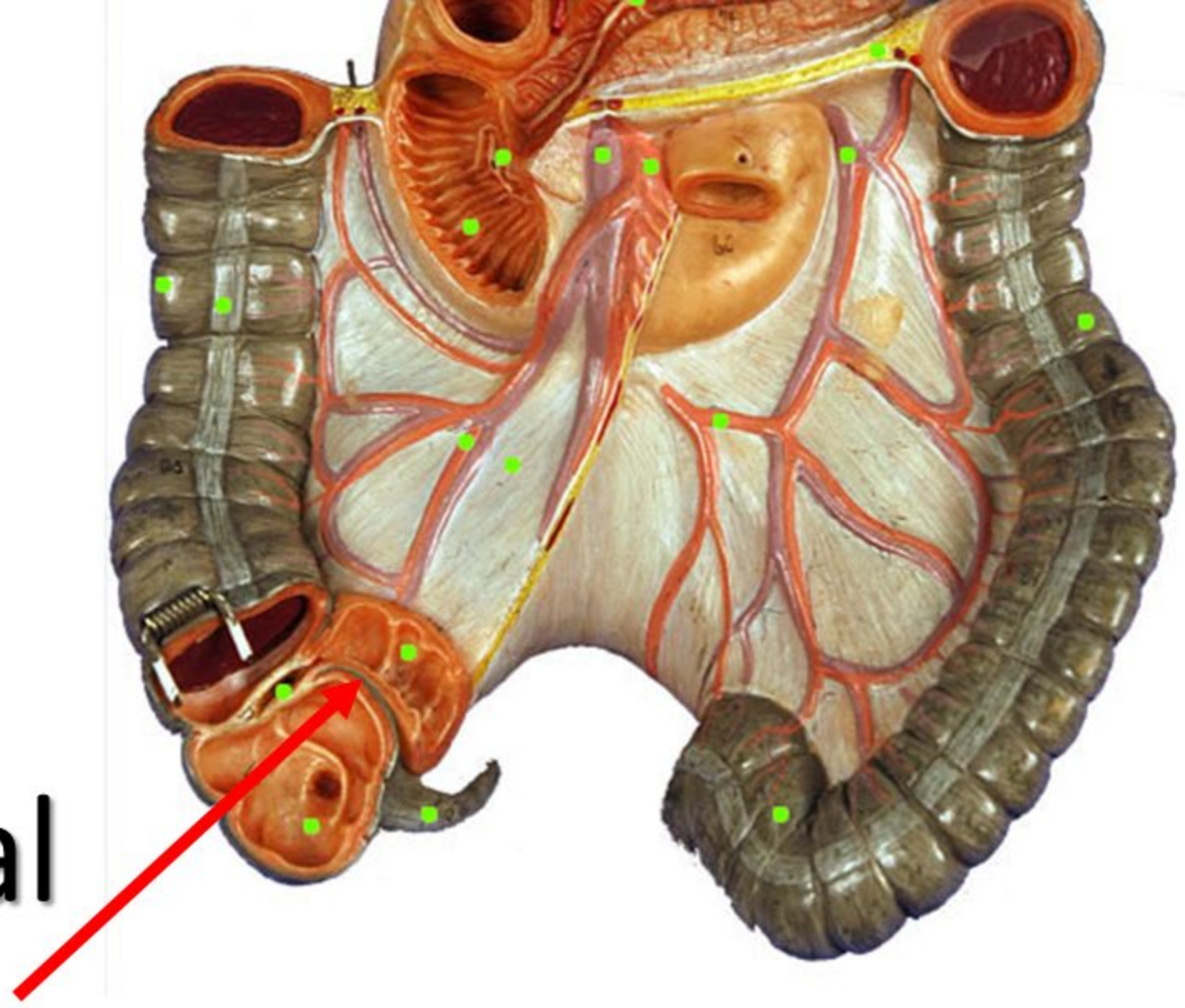


Cecum



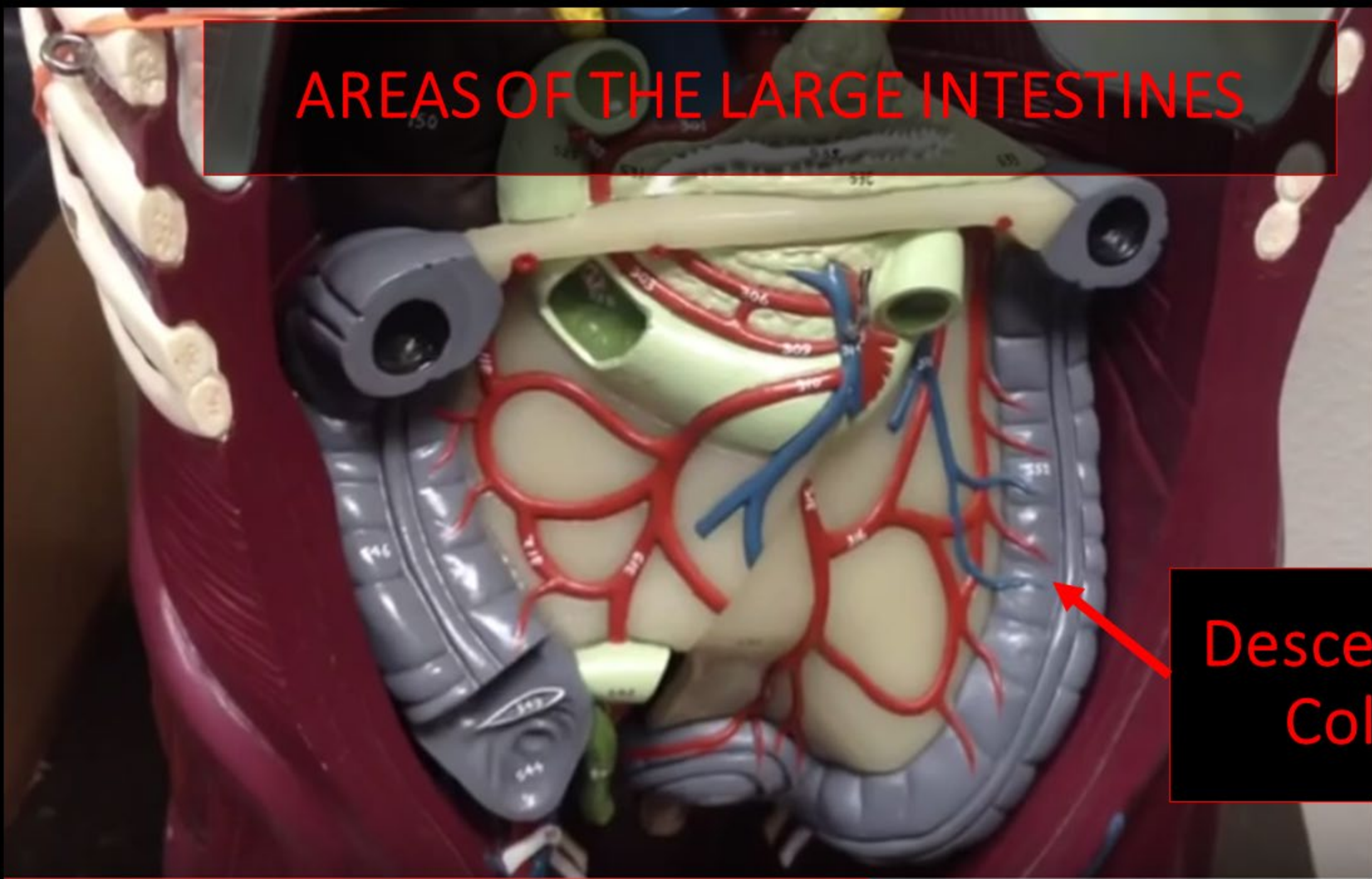


Ileocecal  
Valve



# AREAS OF THE LARGE INTESTINES

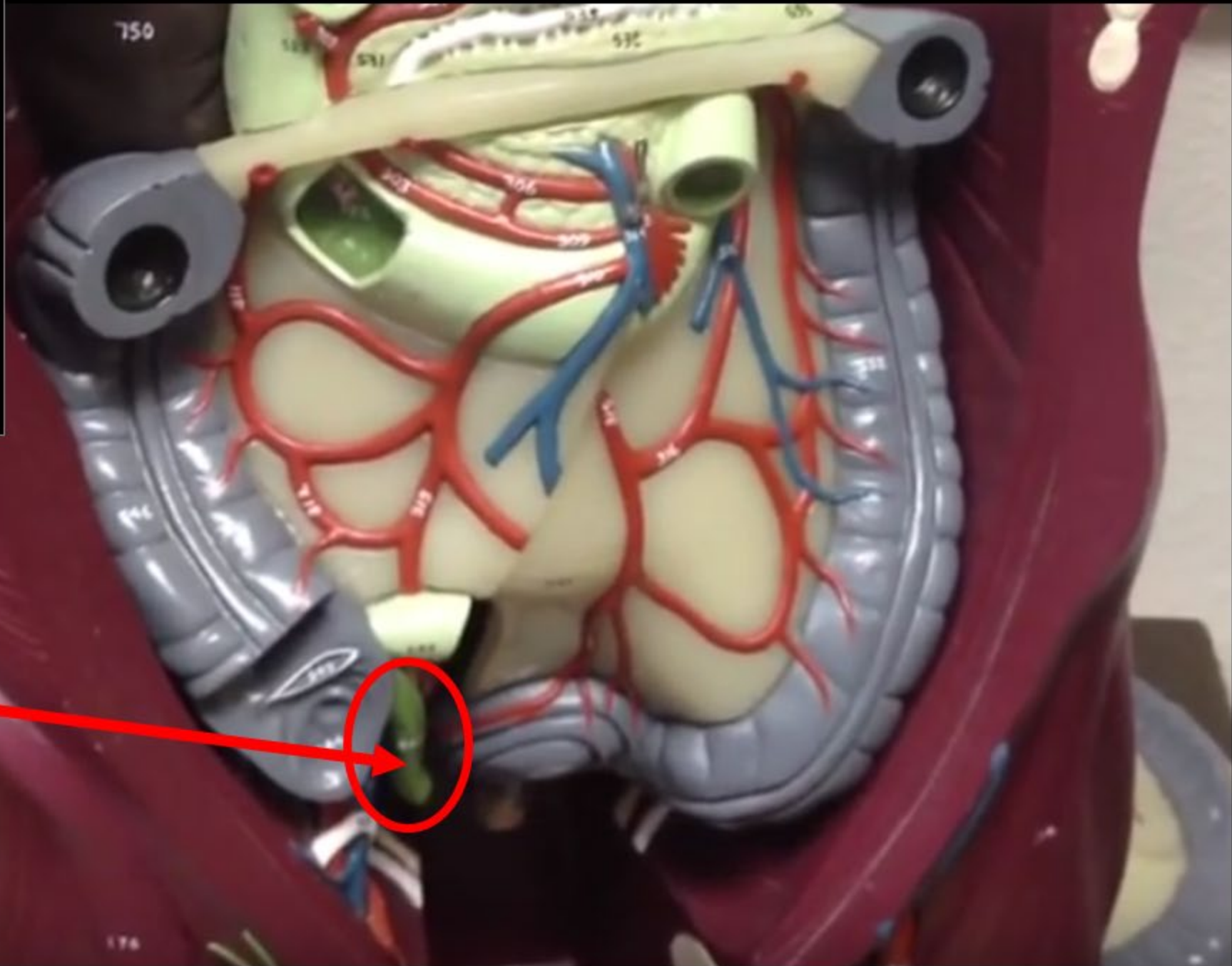
Descending  
Colon



Function = The appendix now functions as a safehouse for healthy bacteria (probiotics).

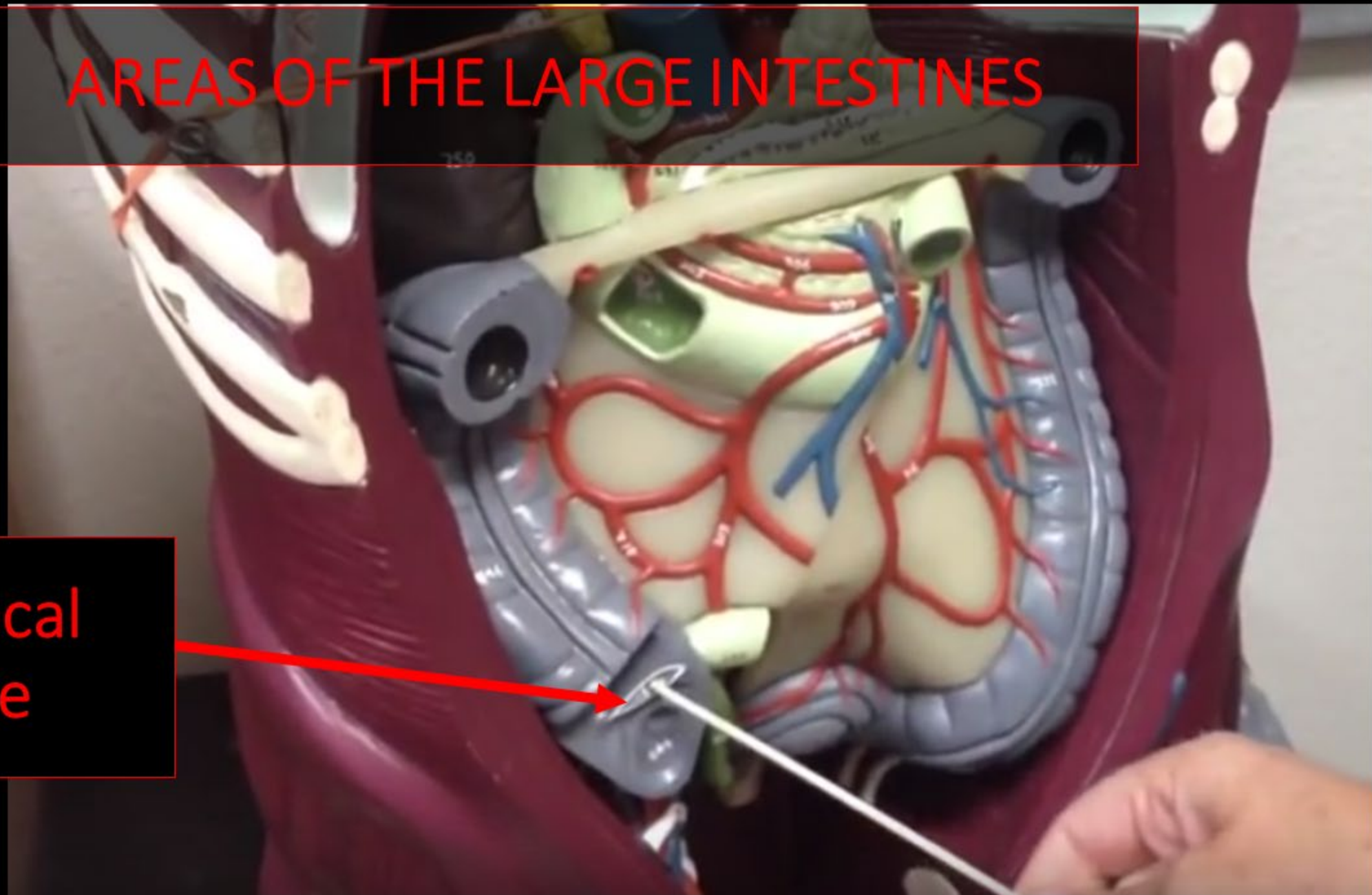
*In the early human, the appendix carried enzymes needed to breakdown cellulose. This organ has lost this function due to evolution.*

**Appendix**  
(the thing in green)

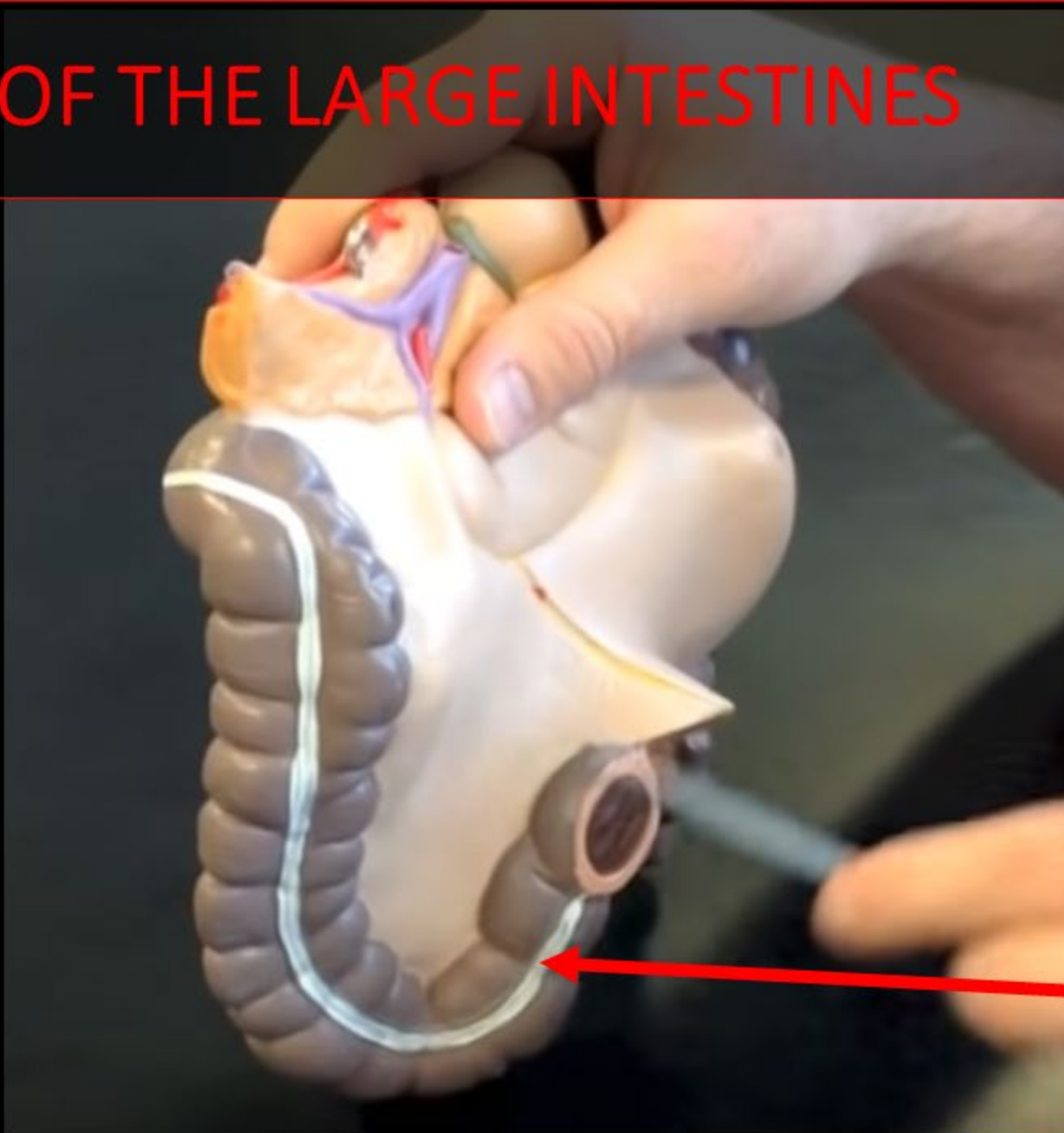


# AREAS OF THE LARGE INTESTINES

Ileocecal  
Valve



# AREAS OF THE LARGE INTESTINES

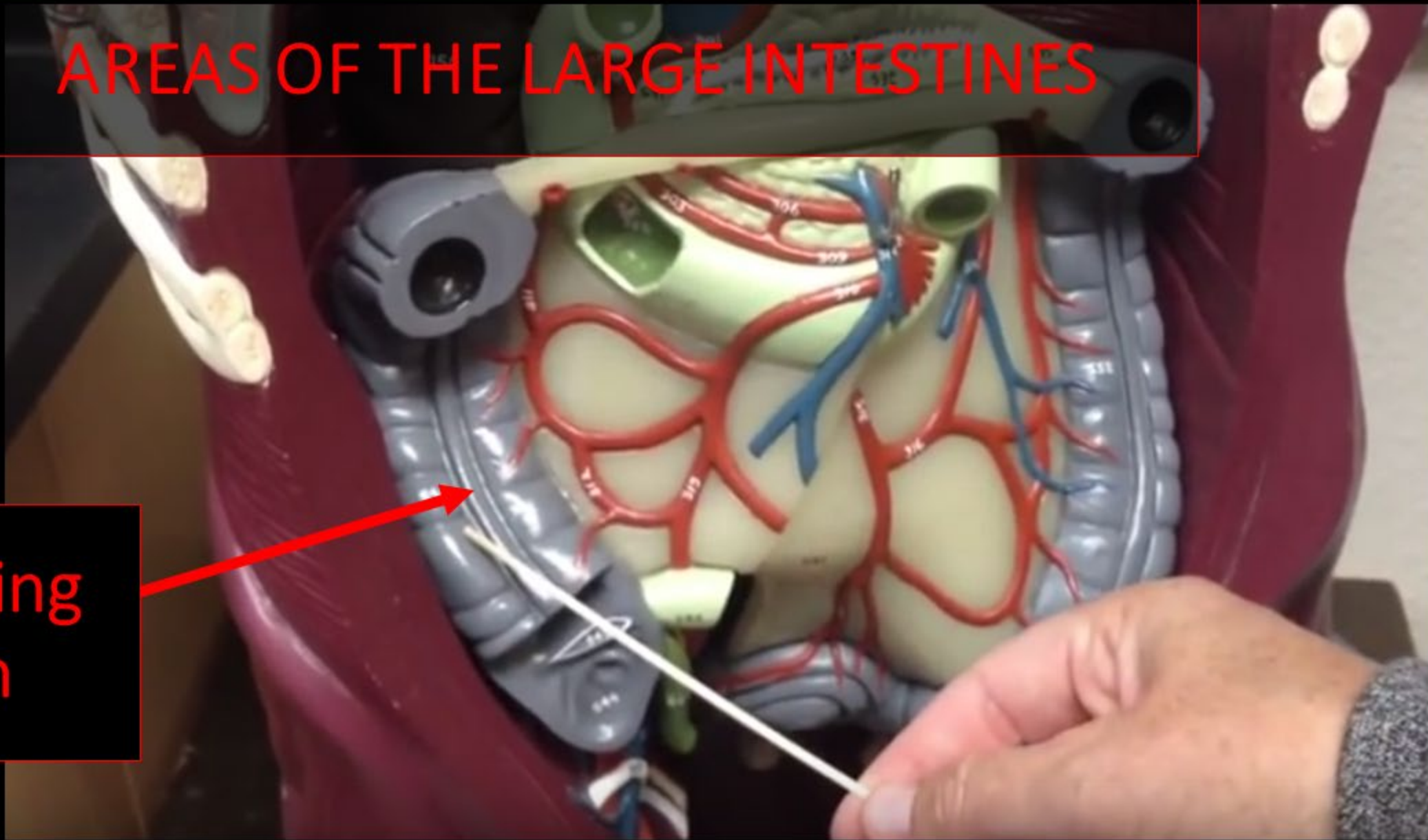


*\*The sigmoid colon starts at the bottom of the descending colon and wraps around back.*

Sigmoid  
Colon

# AREAS OF THE LARGE INTESTINES

Ascending  
Colon



# The Colon / Large Intestine

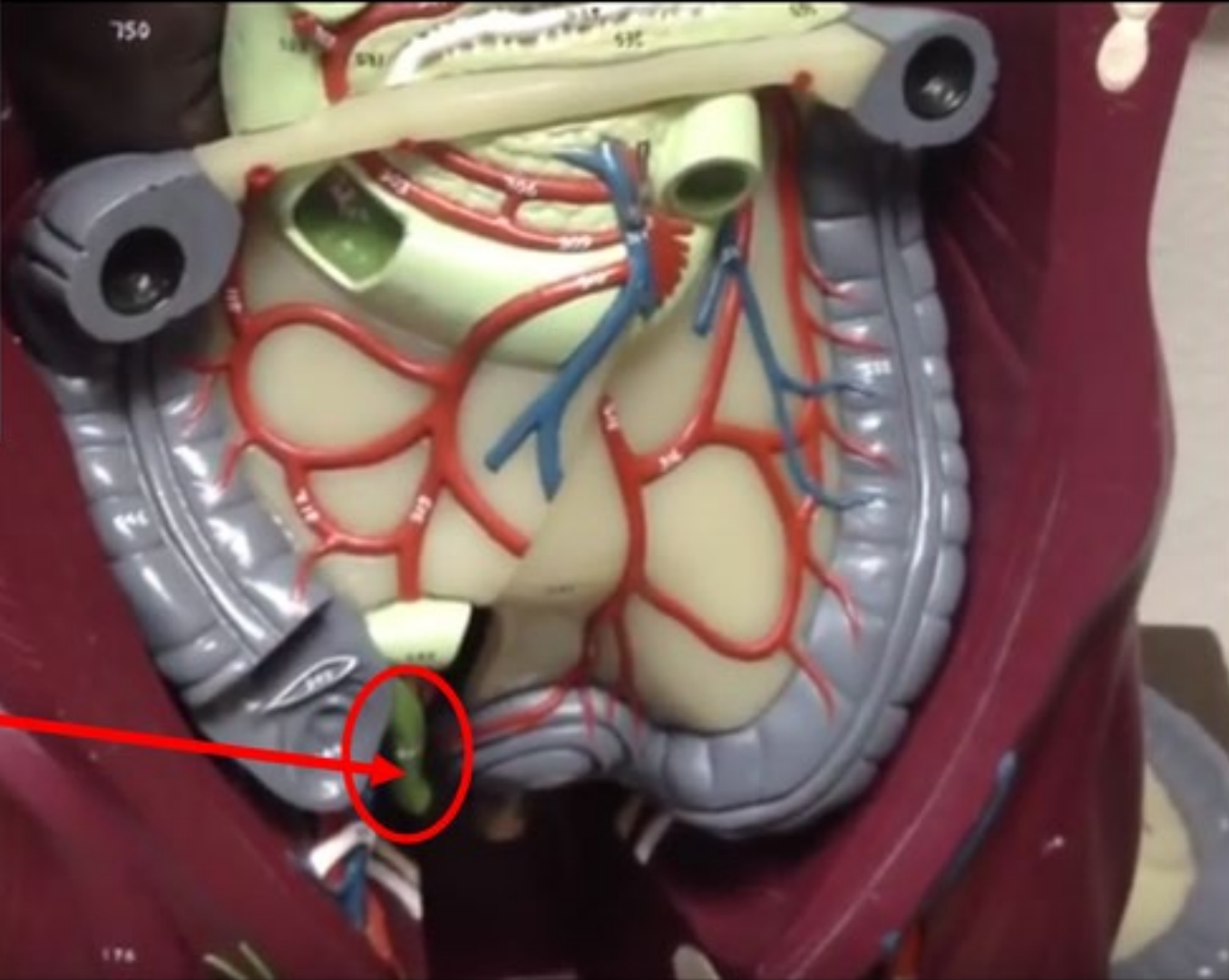
- Food (or chyme) travels from the ileum of the small intestine to the cecum of the large intestine via the ileocecal valve.
- The cecum is the beginning of the large intestine.
- The cecum functions to provide a space for the mixing of bacteria with partially digested food from the small intestine to form feces.

# *The Appendix*

Function= The appendix now functions as a safehouse for healthy bacteria (probiotics).

*In the early human, the appendix carried enzymes needed to breakdown cellulose. This organ has lost this function due to evolution.*

**Appendix**  
(the thing in green)

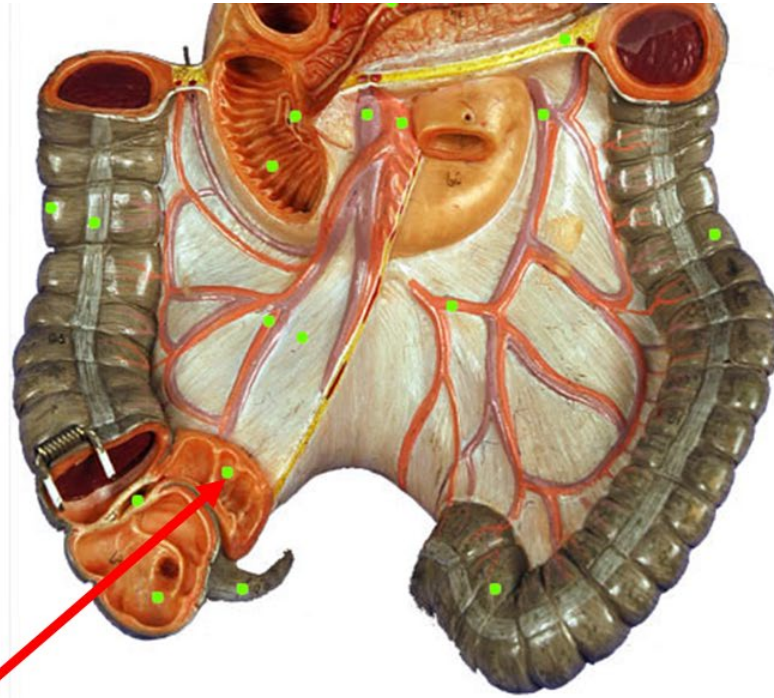




# The Appendix

- **Extending from the inferior end of the large intestine's cecum, the human appendix is a narrow outcropping of tissue. whose resemblance to a worm inspired its alternate name, vermiform (worm-like) appendix.**
- **The appendix now functions to store immune cells and healthy bacteria (probiotics) that aid digestion.**
- **The appendix is sometimes referred to as a vestigial organ, because early humans, the appendix carried enzymes needed to breakdown cellulose.**
- **This organ has since lost this function due to evolution.**

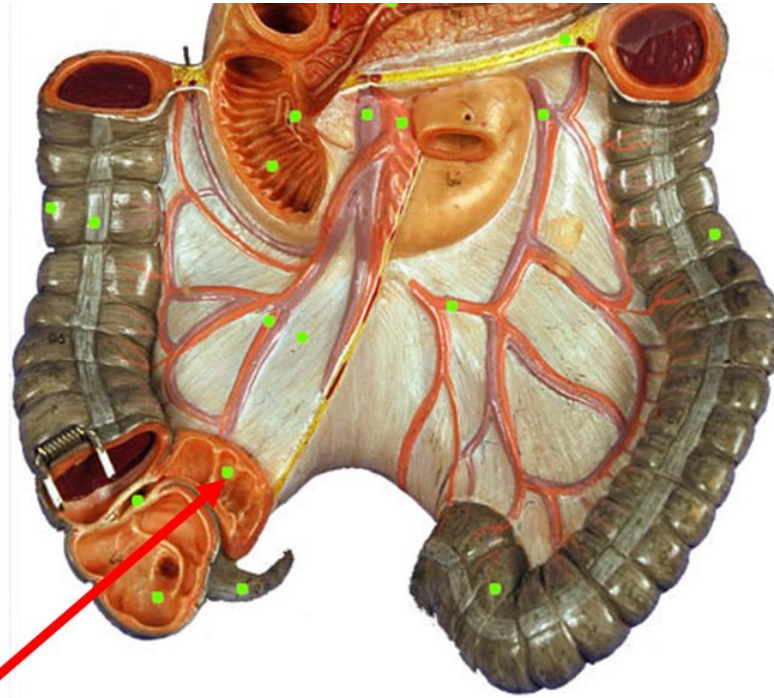
Ileocecal  
Valve



*The ileocecal valve and the  
cecum*

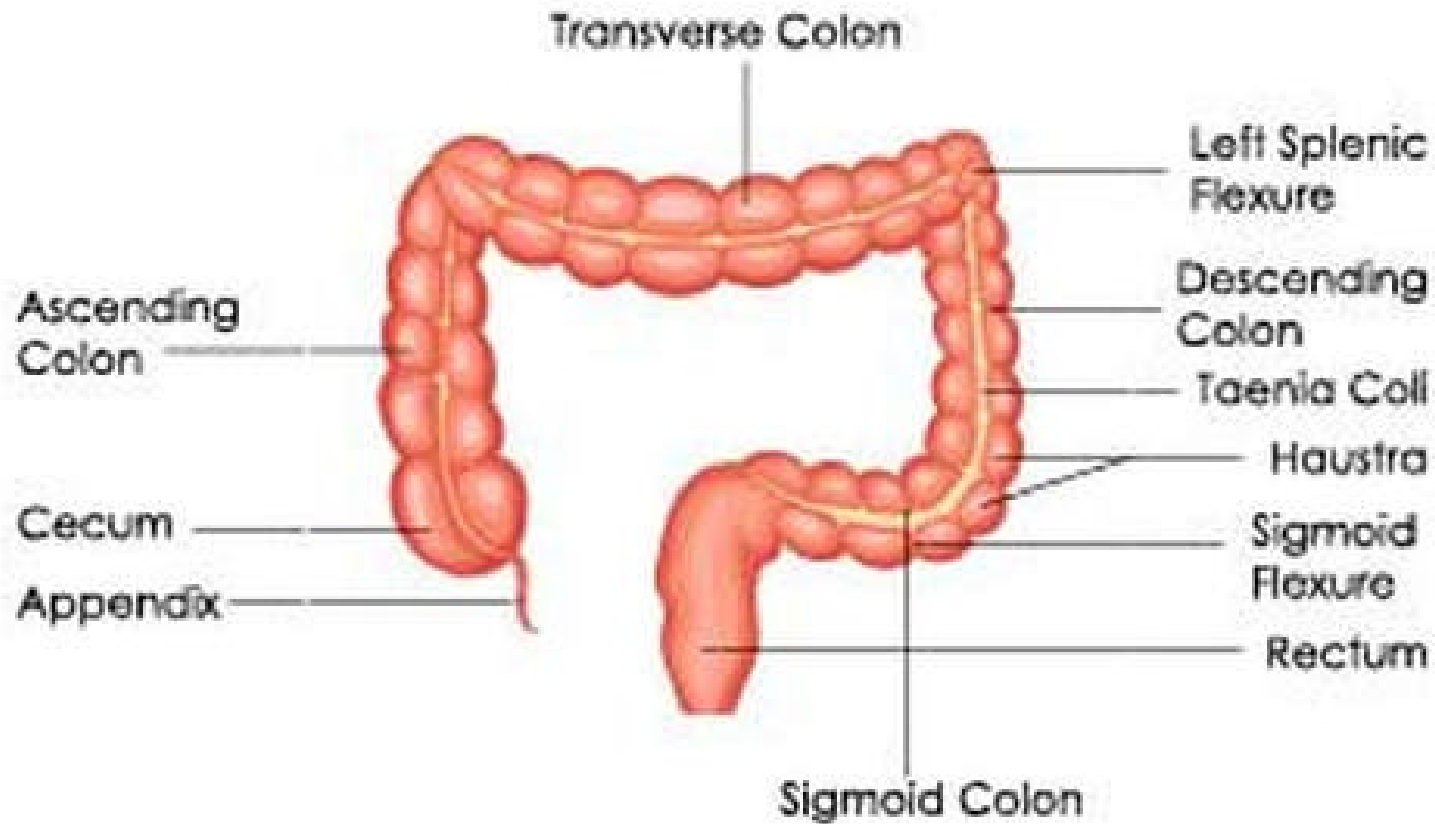
- Chyme (paste of food with gastric juices) leaves the ileum of the small intestine and enter into the cecum of the large intestine through the ileocecal valve.
- The ileocecal valve is a sphincter muscle valve that separates the small intestine and the large intestine.
- It functions to prevent substances flowing back into the ileum once they have reached the cecum.

Ileocecal  
Valve



*The ileocecal valve and the  
cecum*

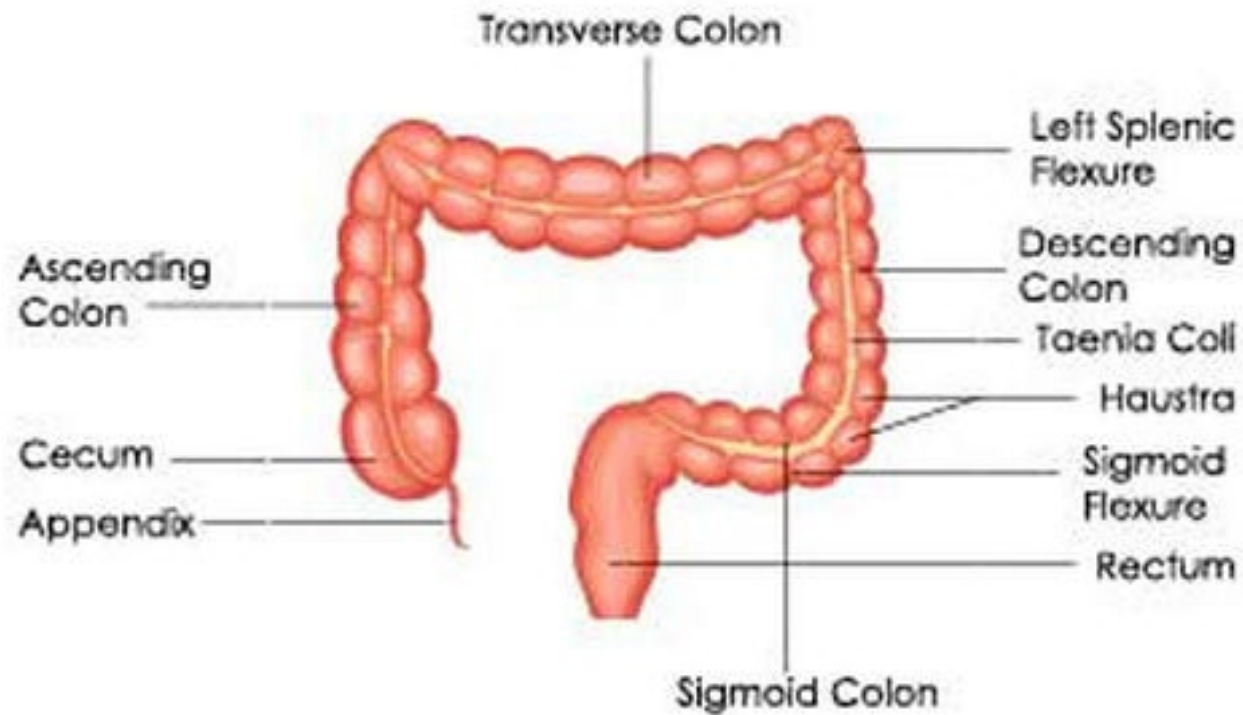
- Once food has been further broken down in the cecum, it will travel up the ascending colon, across the transverse colon, down the descending colon, then through the sigmoid colon, rectum and finally, out the anus.



As the food makes its journey, some water will be absorbed, leaving behind waste products to be eliminated from the body in the form of feces.

# LARGE INTESTINE





# LARGE INTESTINE

The main function of the large intestine (also called the colon) is to concentrate and produce waste in the form of feces.