

**SBI3U**

# The Circulatory System



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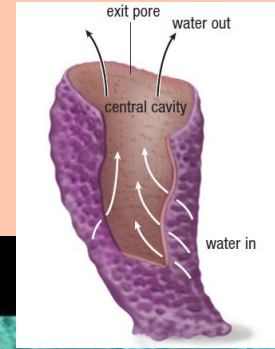
# 11.1 The Need for a Circulatory system.

The circulatory system is responsible for transporting (or circulating)

- nutrients,
- dissolved gases,
- wastes, and
- other chemicals to and from individual cells in an organism

# Some animals do not need a whole “system”

E.g. Circulation in the **sponge** is achieved by setting up a **current** that pulls water in through the **body pores** and out through the opening



# A complex circulatory system is an evolutionary adaptation to increasing body size

- In **larger** and more **complex multicellular** animals with more than 2 cell layers, some body cells do not come into contact with the fluids of the external environment — air or water.
  - A circulatory system ensures that oxygen and nutrients are delivered to every cell and that waste products that are removed from cells are released into the external environment.

# Features of a Circulatory System

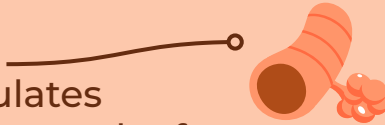
## Fluid

Transports materials through the body



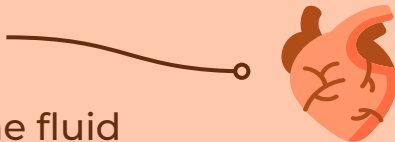
## Tubes

Fluid circulates through network of tubes

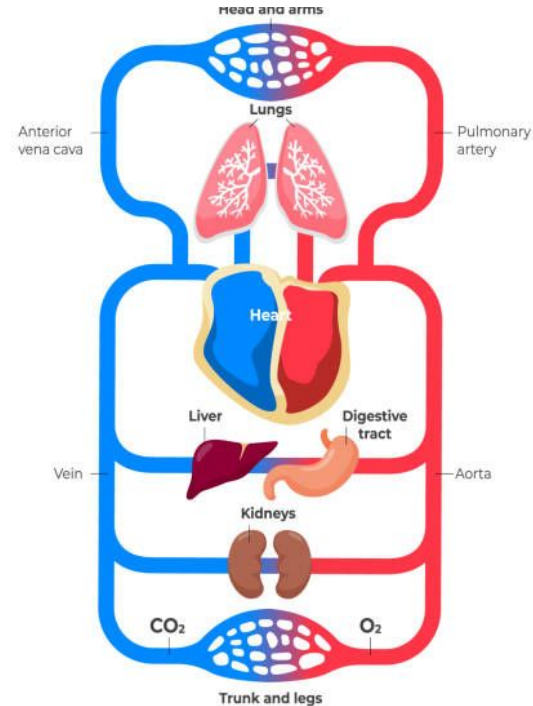


## Pump

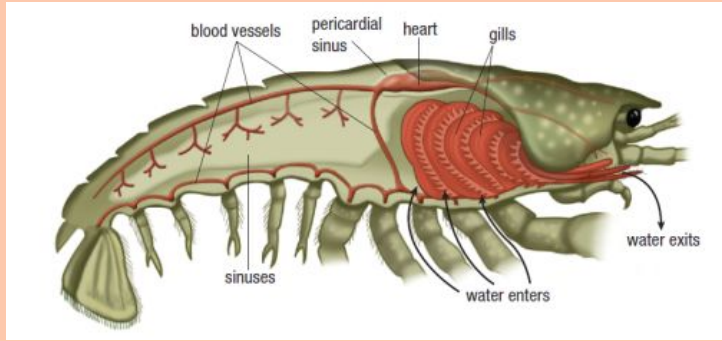
Pushes the fluid through the tubes



Human Circulatory System



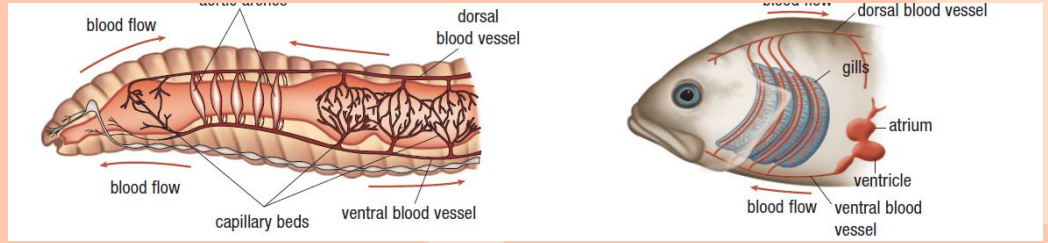
# Types of Circulatory Systems



## Open

The circulating fluid is pumped into an interconnected system of **body cavities**, or **sinuses**, where it bathes the cells directly.

The circulating fluid, called **hemolymph**, is a mixture of blood and tissue fluid.



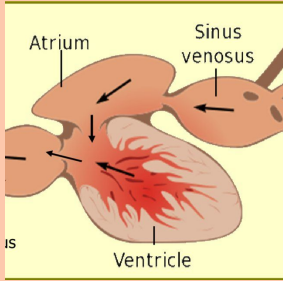
## Closed

All **vertebrates**, as well as some **invertebrates**, have closed circulatory systems.

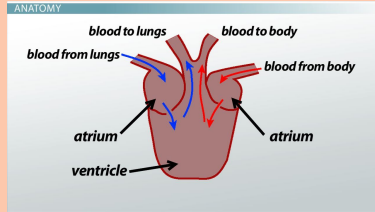
The fluid (often blood) is **contained** within a network of **tubes**, or blood vessels.

The tissue fluid surrounds the cells and provides a medium for **diffusion** of substances from the bloodstream to the cells.

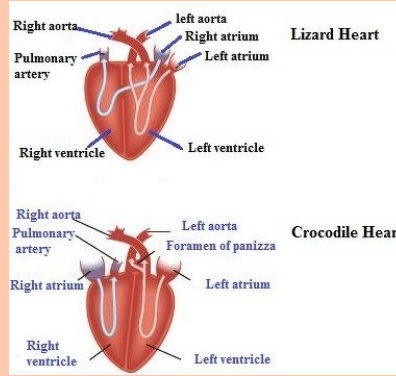
# Evolution of the Vertebrate Heart



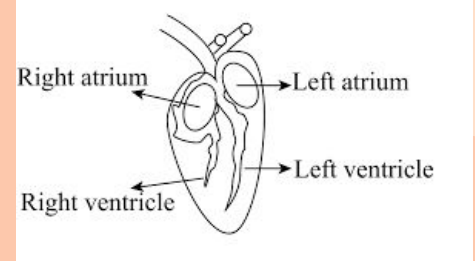
**Fish**



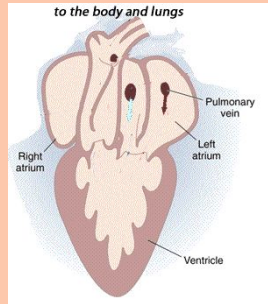
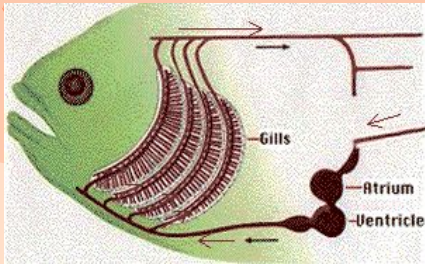
**Amphibian**



**Reptile**



**Mammal or Bird**



As animals evolved in size and complexity, the heart evolved from a simple two-chambered structure to a four-chambered structure.



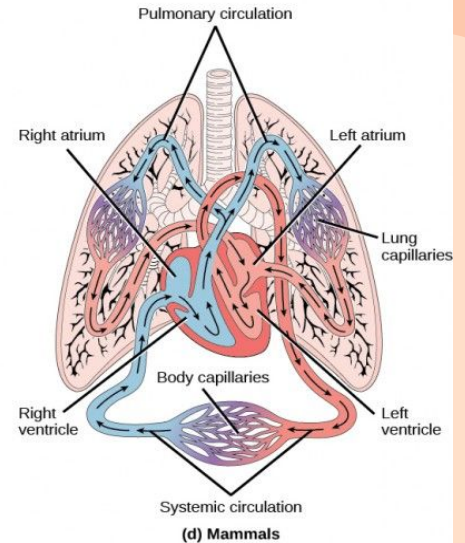
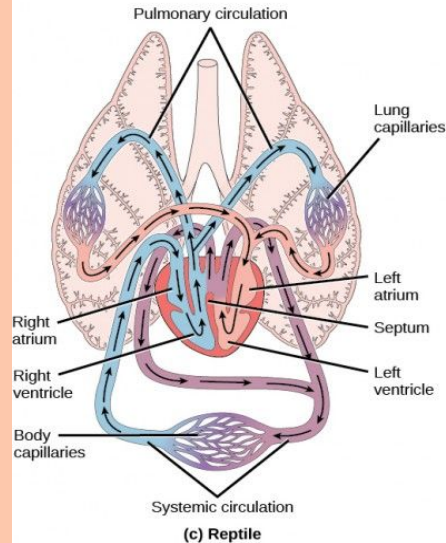
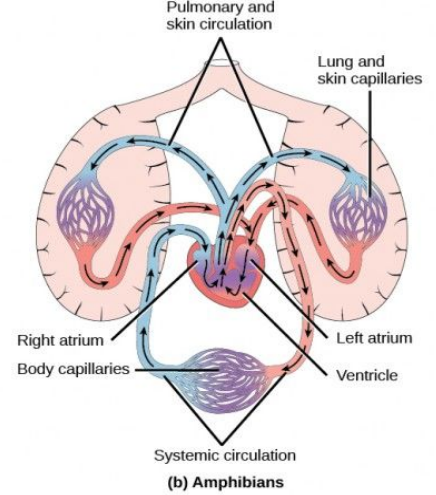
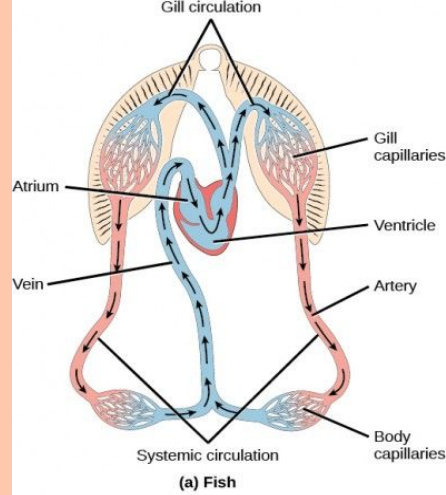
# Circulatory systems:

a) Fish

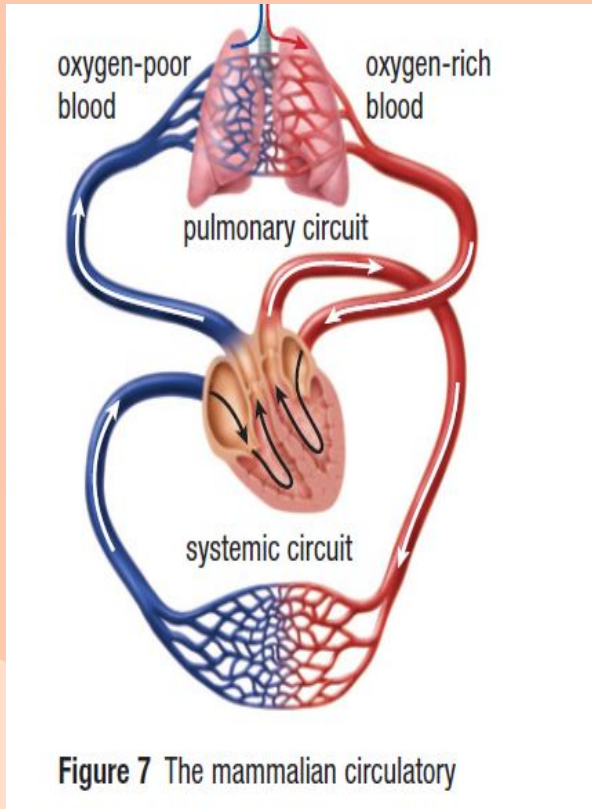
b) Amphibians

c) Reptiles

d) Mammals (+ Birds + Crocodilians)



# The two-circuit circulatory system




Mammals, birds and crocodilians have evolved to have an even more complex system

Pulmonary circuit – the part of the circulatory system that delivers blood to the lungs

Systemic circuit – the part of the circulatory system that delivers blood around the body

The background features a large, stylized orange and white profile of a human head. Inside the head, there are illustrations of a brain, sperm cells, and a heart. The word "Homework" is written in large, bold, brown letters across the center of the head profile.

# Homework

A small illustration of a heart with red and orange tones, positioned to the left of the text.

P. 481: 1, 2, 4b, 5, 6

What kind of car did the heart surgeon drive to work?

A small illustration of a slice of pizza with a white crust, red sauce, and toppings, positioned to the right of the text.

*A beater!*

# 11.2

## **Blood: A Fluid Tissue**

p. 482 – 486

# What you already know about the blood!



## Blood types

4 different types:

**A, B, AB, O**

Inherited ( $I^A$ ,  $I^B$ ,  $I^A I^B$ ,  $ii$ )



## White blood cells

Are warriors defending  
our bodies from bacteria  
and viruses



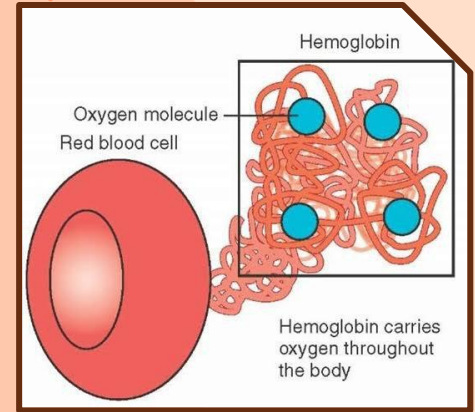
## Platelets

Control bleeding unless  
there is an abnormality  
(e.g. thrombocytopenia,  
hemophilia)



# Hemoglobin

Protein found in red blood cells



## 4 iron molecules/hemoglobin molecule

carry oxygen to body cells (aerobic cellular respiration)

## Red Blood Cells & Plasma

pick up  $\text{CO}_2$  and  $\text{H}^+$  ions for delivery to the alveoli from the body cells.

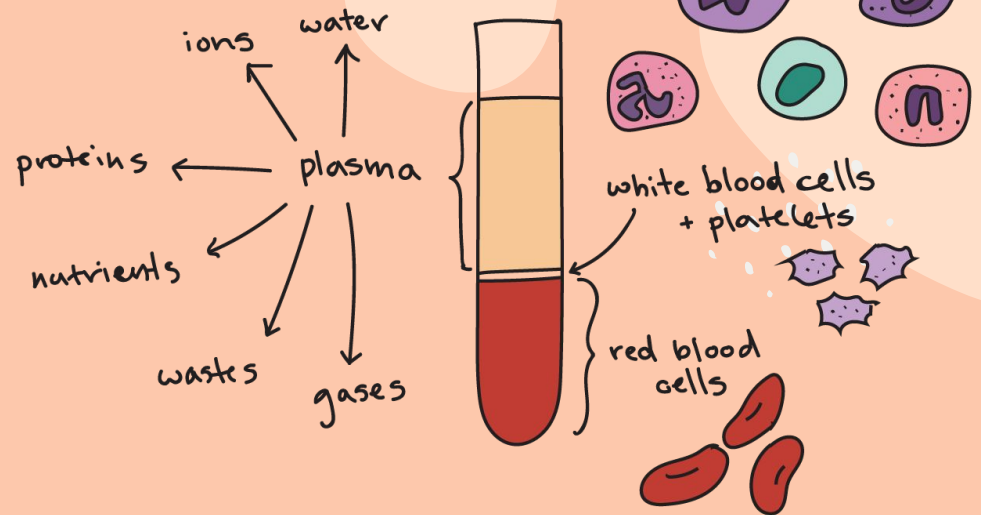


# 4 to 5 litres of blood

Depends on your size! That's 2 - 2 litre pop bottles!

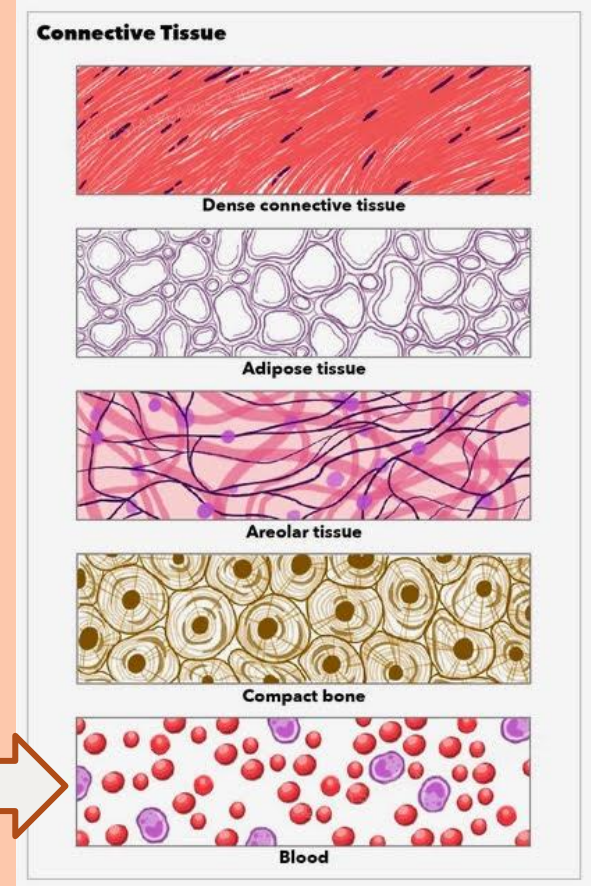
## Blood is a connective tissue

It contains a protein matrix.



# Why is blood considered a connective tissue?

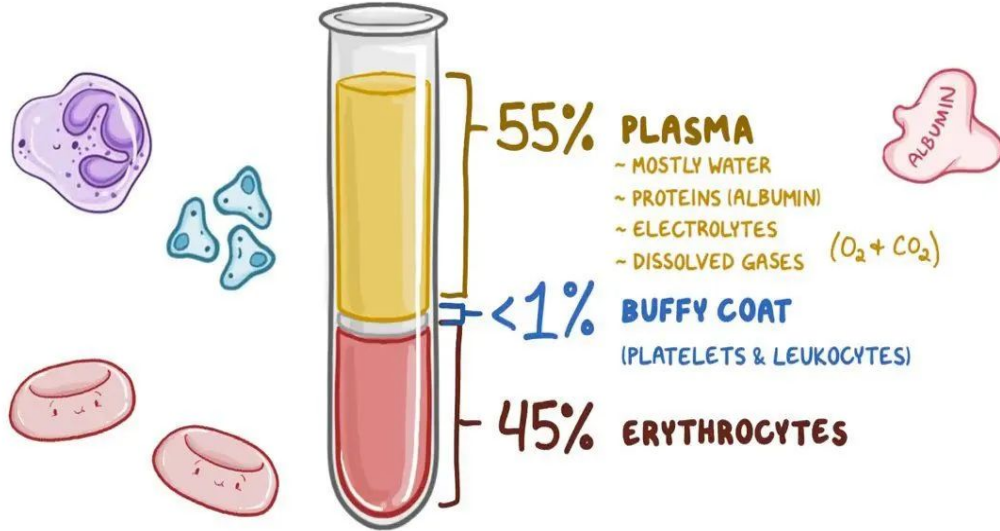
1. Embryologically, it has the same origins as other connective tissues in the body
2. It connects the body systems together





# Two Main Components

## BLOOD



## Intercellular matrix

**Plasma:** yellow-coloured liquid

## Cellular component

Red blood cells,  
white blood cells &  
platelets

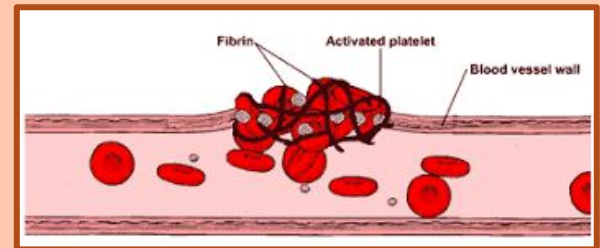
# Plasma

## 90% Water

- Contains dissolved oxygen, proteins, and nutrients. {glucose, minerals [Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, Cl<sup>1-</sup>], vitamins}
- Contains waste products of aerobic cellular respiration and dissolved CO<sub>2</sub>

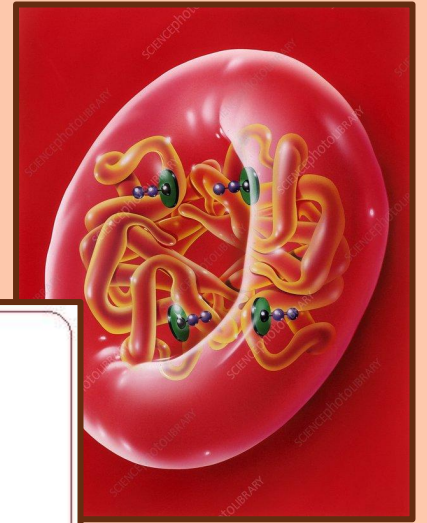
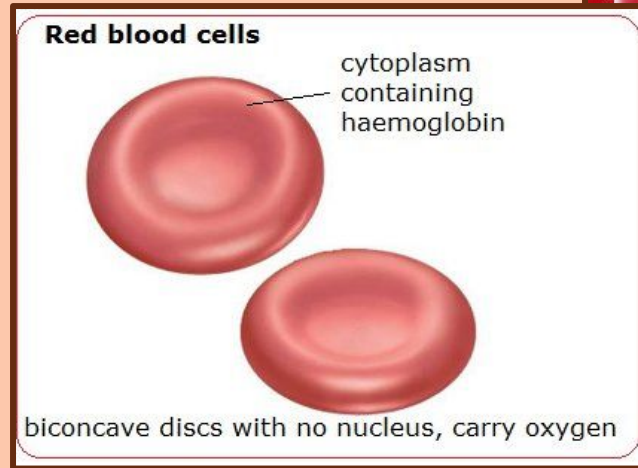
## 7% Blood Proteins

- Albumin - maintains water balance and blood volume
- Globulin
  - transports lipids, cholesterol, fat soluble vitamins
  - immunoglobulins are part of our immune response to infection (antibodies)
- Fibrinogen - critical role in blood clotting



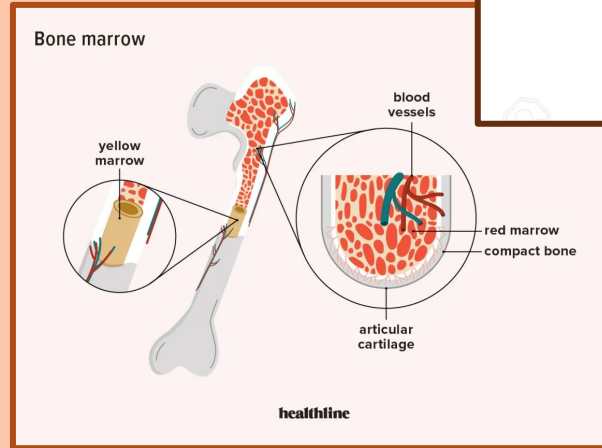
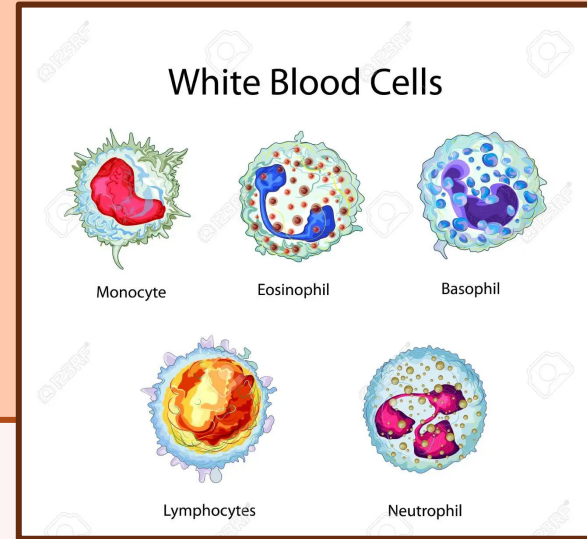
# Cellular Components: Red Blood Cells (Erythrocytes)

- Contain hemoglobin
- Tiny biconcave disks with no nucleus
- Formed from stem cells in bone marrow
- Last about 120 days in the body
- Produced in the bone marrow
- Removed and recycled by the liver and spleen

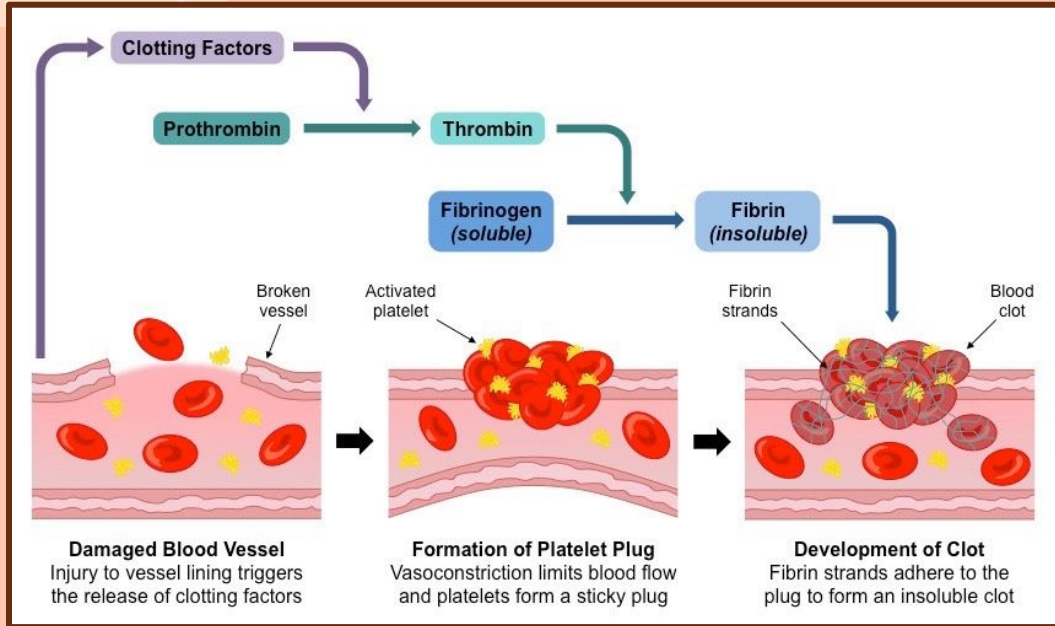


# Cellular Components: White Blood Cells (Leukocytes)

- Formed in **bone marrow**
- Has a **nucleus**
- **First line of defense** against disease-causing microorganisms and viruses
- 2 categories:
  1. **Granular** Granules contain chemicals that attack the bacteria (neutrophils, eosinophils, basophils)
  2. **Agranular** Phagocytose the bacteria (lymphocytes, monocytes)

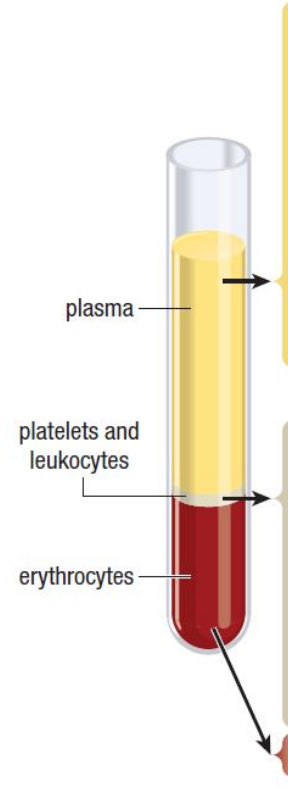


# Cellular Components: Platelets



- Small cell fragments produced in bone marrow
- Important for clotting of blood
- But, if the clot gets loose in the bloodstream, they may block vessels

# Summary Chart



Components	Relative amounts	Functions
<b>Plasma portion (55 %–58 % of total volume):</b>		
Water	91 %–92 % of plasma volume	Solvent
Plasma proteins (albumin, globulins, fibrinogen, and so on)	7 %–8 %	Defence, clotting, lipid transport, roles in extracellular fluid volume, and so on
Ions, sugars, lipids, amino acids, hormones, vitamins, dissolved gases, urea and uric acid (metabolic wastes)	1 %–2 %	Roles in extracellular fluid volume, pH, eliminating waste products, and so on
<b>Cellular portion (42 %–45 % of total volume):</b>		
Platelets	250 000–300 000 per microlitre	Roles in clotting
Leukocytes (white blood cells)		
Neutrophils	3000–6750	Phagocytosis during inflammation
Lymphocytes	1000–2700	Immune response
Monocytes/macrophages	150–720	Phagocytosis in all defence responses
Eosinophils	100–360	Defence against parasitic worms
Basophils	25–90	Secrete substances for inflammatory response and for fat removal from blood
Erythrocytes (red blood cells)	4 800 000–5 400 000	Oxygen, carbon dioxide transport

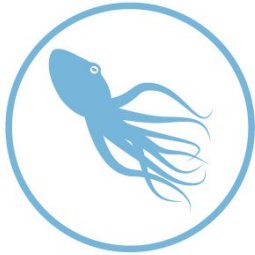
# THE DIFFERENT COLOURS OF BLOOD



## Red

HUMANS AND THE MAJORITY OF OTHER VERTEBRATES

HAEMOGLOBIN



## Blue

SPIDERS, CRUSTACEANS, SOME MOLLUSCS, OCTOPUSES & SQUID

HAEMOCYANIN



## Green

SOME SEGMENTED WORMS, SOME LEECHES, & SOME MARINE WORMS

CHLOROCRUORIN



## Violet

MARINE WORMS INCLUDING PEANUT WORMS & BRACHIOPODS

HAEMERYTHRIN

## Hemoglobin

Contains iron to carry oxygen

- Red blood

## Hemocyanin

Uses copper to carry oxygen

- Blue blood
- Used by octopuses, lobsters, horseshoe crabs

## Other

- Violet for marine worms
- Green blood for leeches

# Carrying Oxygen

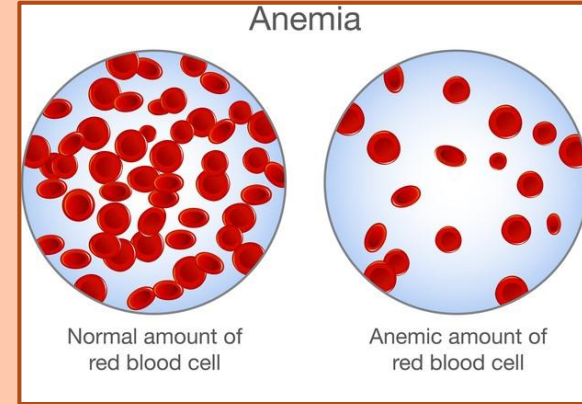


## Weird

New Guinea lizards – use hemoglobin, but blood is green because the byproduct of dead red blood cells (**biliverdin**) is not eliminated.

# Anemia – Counting Blood Cells

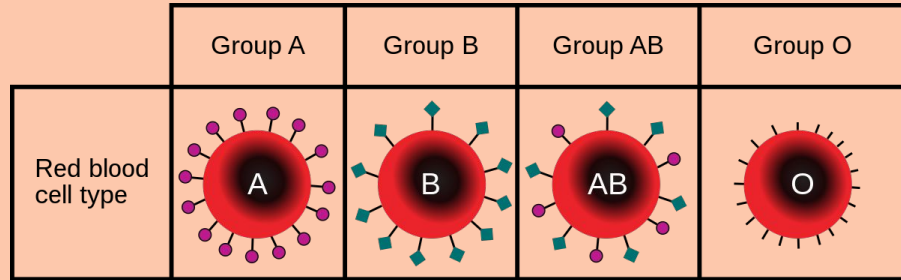
- A lower than normal erythrocyte count indicates that a person has a condition known as **anemia**.
- The amount of oxygen delivered to the cells is **diminished** in a person with anemia, and they may feel tired and run down.
- Anemia is caused by:
  1. **Blood loss** – an external injury, heavy menstrual cycle, bleeding stomach ulcer
  2. **Lack of production** of red blood cells
    - e.g. aplastic anemia where bone marrow does not make enough blood cells
    - e.g. **deficiency of iron** in the diet: Iron in the heme groups enables oxygen to attach to the hemoglobin molecules.
  3. High rates of **red blood cell destruction** (e.g. sickle cell anemia)





# Blood Types

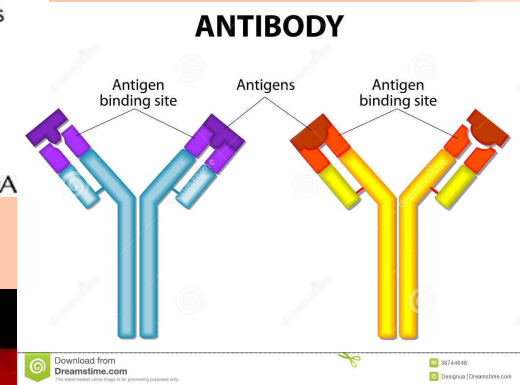
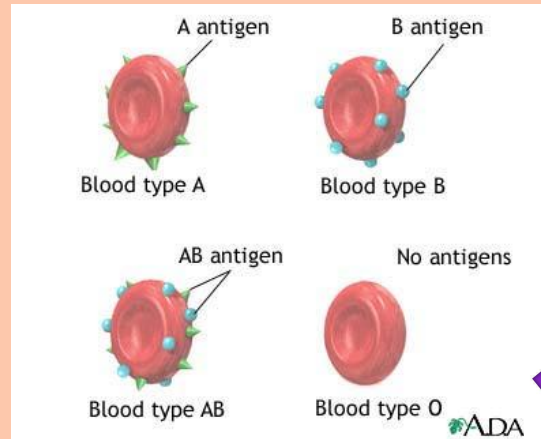
- Four blood types: **A**, **B**, **AB**, and **O**.
- Blood types are determined by the presence (or absence) of different sugars, called markers, on the cell membranes of **erythrocytes**.



- Incompatibility occurs because the markers act as antigens, which are considered foreign material.

# Blood Types

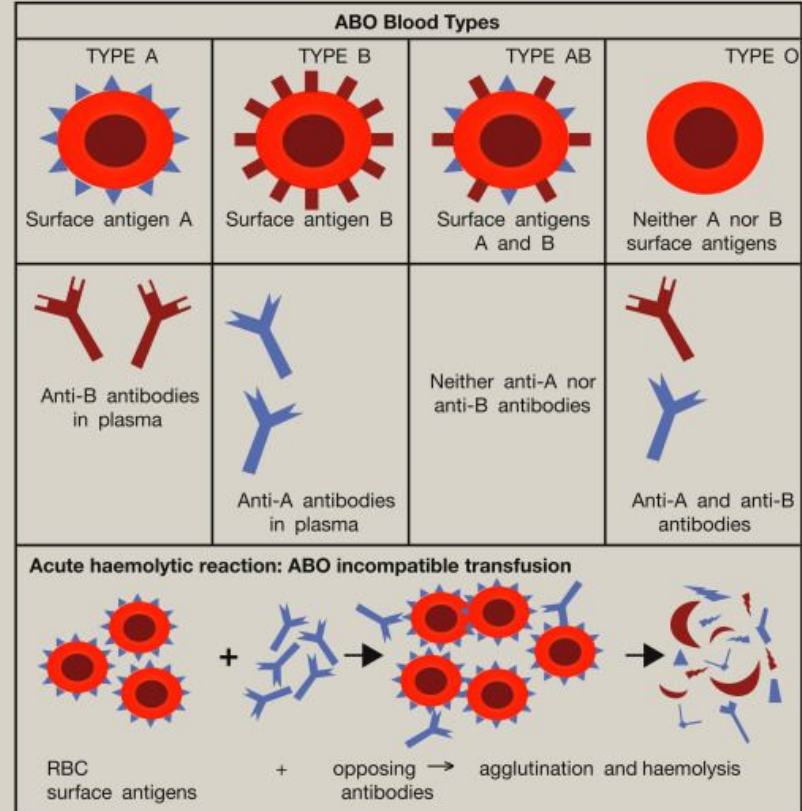
- When the immune system detects **antigens**, it produces **antibodies** that attach to the antigens, causing the blood cells to **clump together** (agglutination)
- Clumping blocks blood vessels and **prevents the circulation of blood** and delivery of oxygen



# Blood Types

- For example, a person with type B blood is given type A blood.
- The antibodies in their blood (anti-A antibodies) will respond to the markers on the type A blood.
- The blood will clump and the cells will die as a result.

Blood type and ABO-incompatible acute haemolytic transfusion reaction

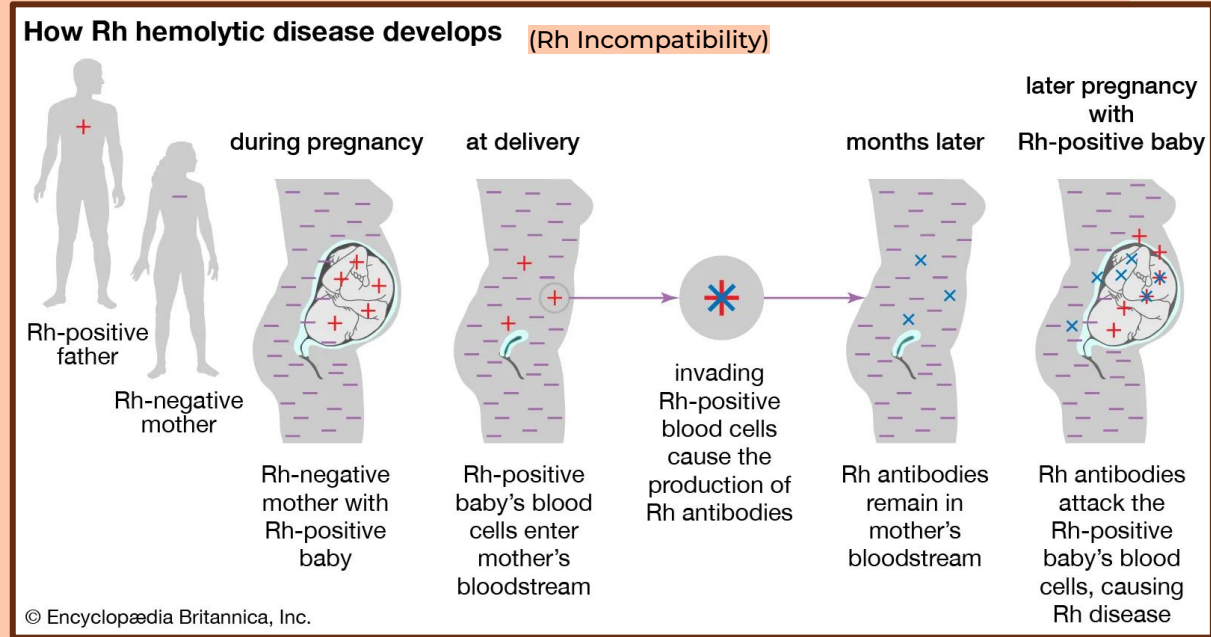


# Rhesus Factor (Rh)

The Rh factor is a protein on the surface of the red blood cell.

- **85%** of the population has the protein = **Rh-positive**
- **15%** are Rh-negative

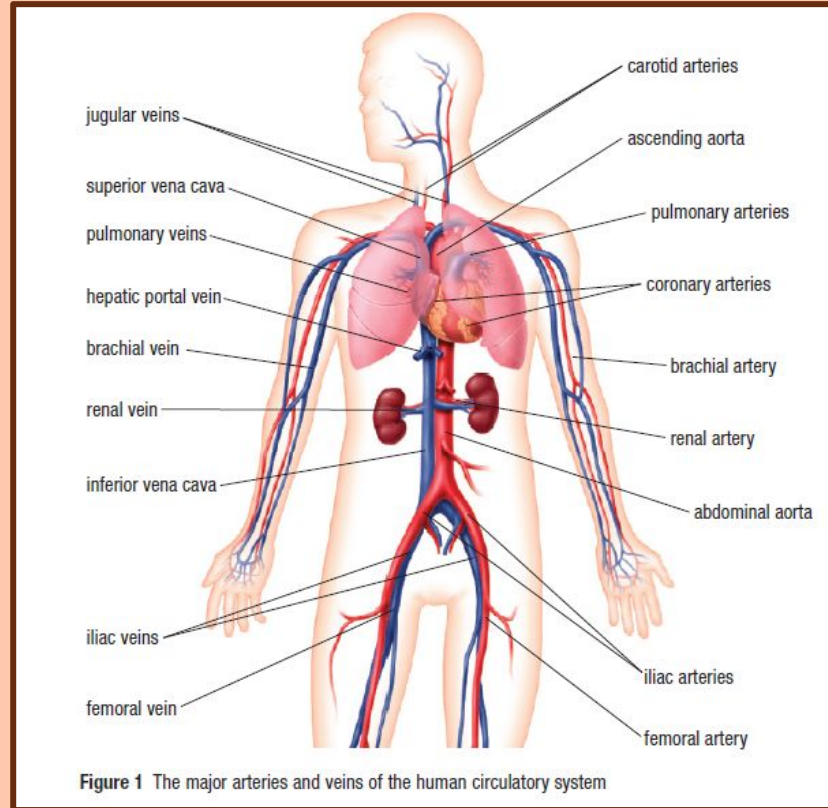
There are **22** different antigens that are rare and **11** antigen groups that are common.



# Homework

P. 486: 2, 3, 4 (risk only), 6  
Complete concept map

# 10.3 Blood Vessels in the Body

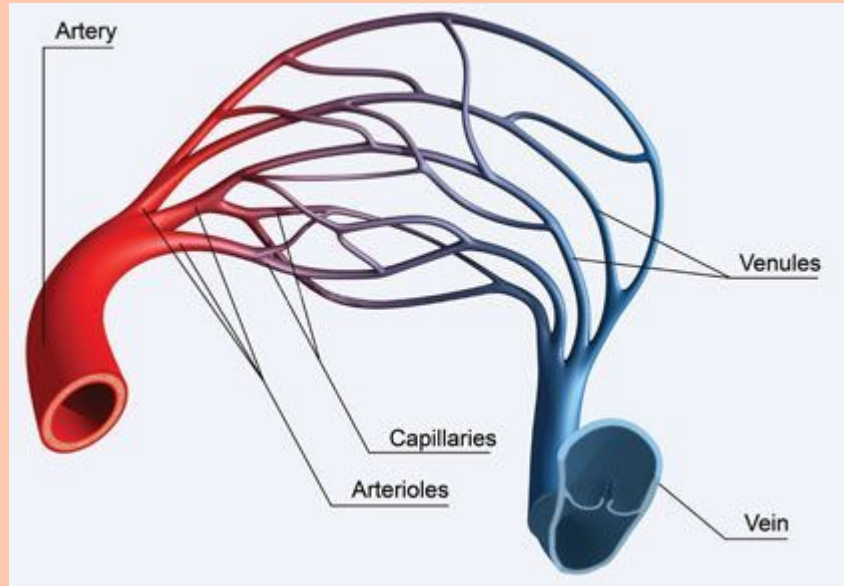


# Blood Vessels

## Arteries

Carry blood away from the heart

## Arterioles



## Capillaries

Link arteries and veins

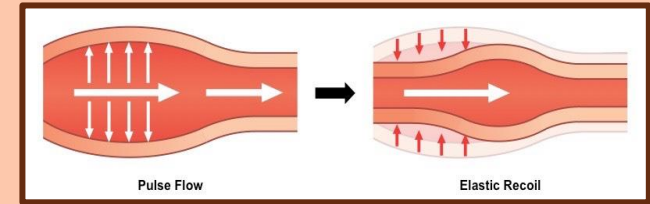
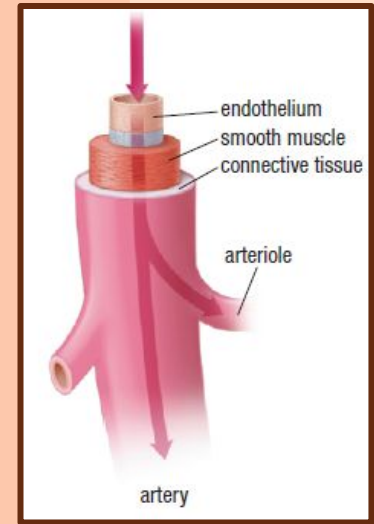
## Venules

## Veins

Bring blood towards the heart

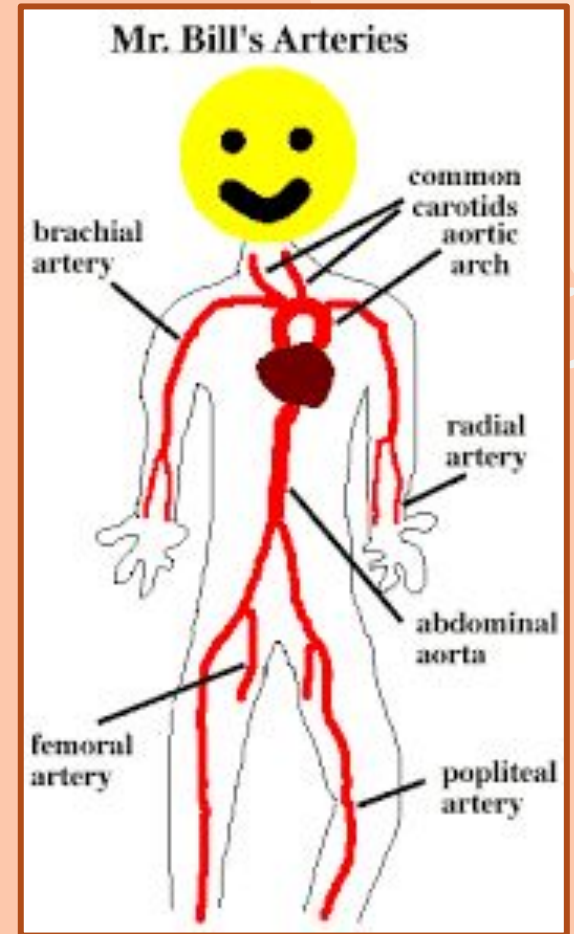
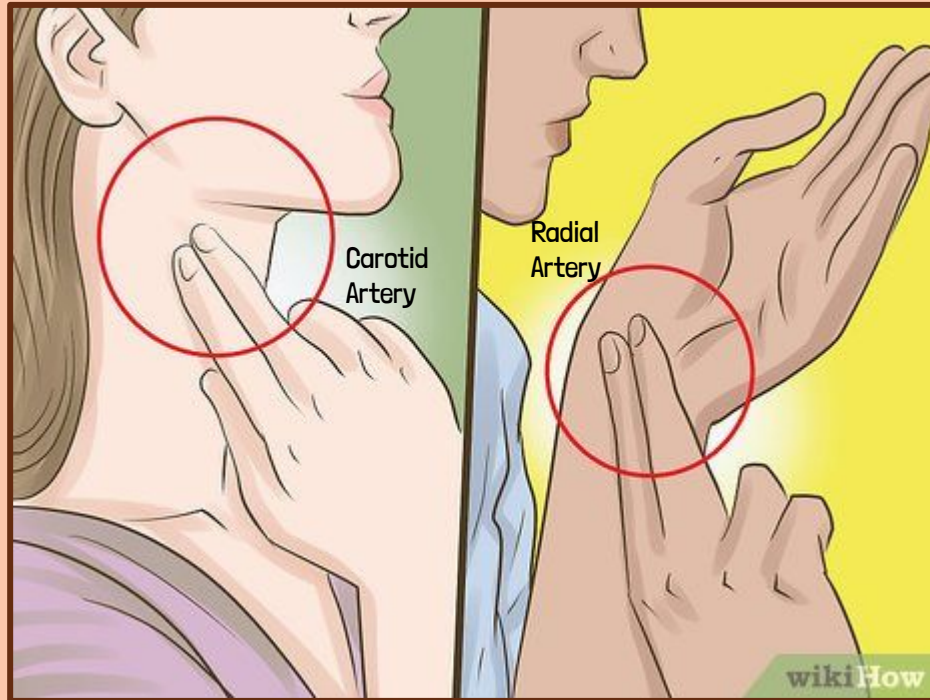
# Arteries

- Arteries carry blood away from the heart to the tissues
- There are 3 layers of tissue in arteries that provide strength and elasticity
  - Endothelium
  - Smooth muscle
  - Connective tissue
- Arteries expand slightly when the heart contracts, return to original size when the heart relaxes
  - This expansion can be felt as a pulse
- Arteries branch into arterioles whose diameter can be controlled by the nervous system by acting on the smooth muscle

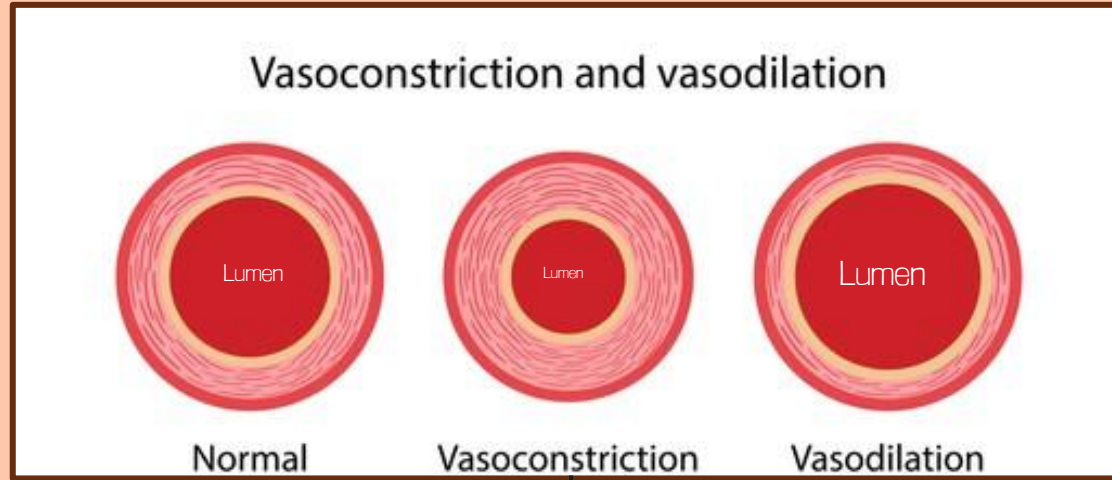




# Finding your Pulse!



# Controlling Blood Flow in Arterioles



Muscle walls contract  
= ↓ area for blood flow

(small lumen)

Muscle walls relax  
= ↑ area for blood flow

(large lumen)

# Controlling Blood Flow in Arterioles



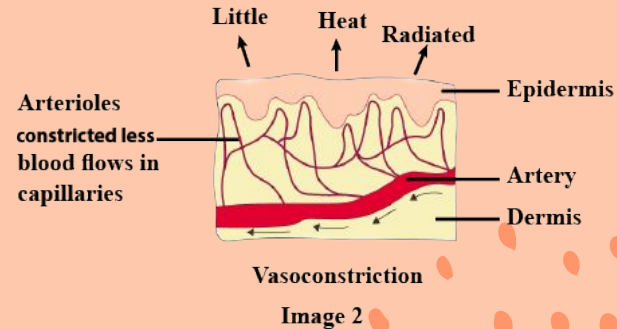
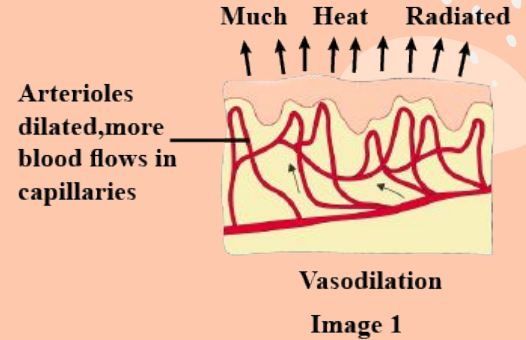
## Vasodilation

- an increase in the diameter of arterioles that increases the blood flow to tissues
  - E.g. blushing

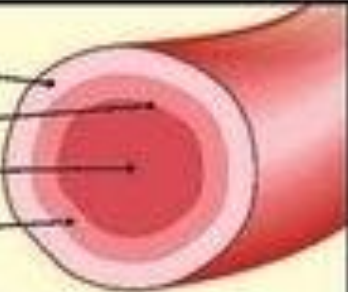
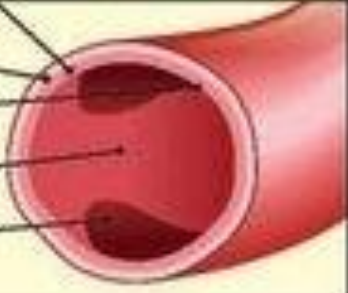



## Vasoconstriction

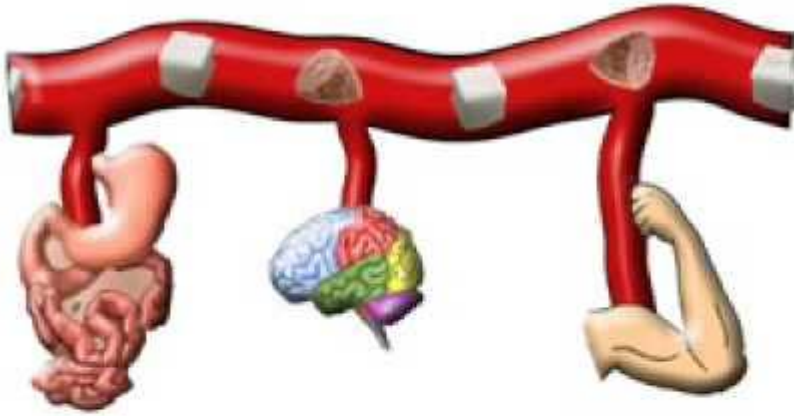
- a decrease in diameter of arterioles that decreases blood flow to tissues
  - E.g. Pale fingers when they are cold



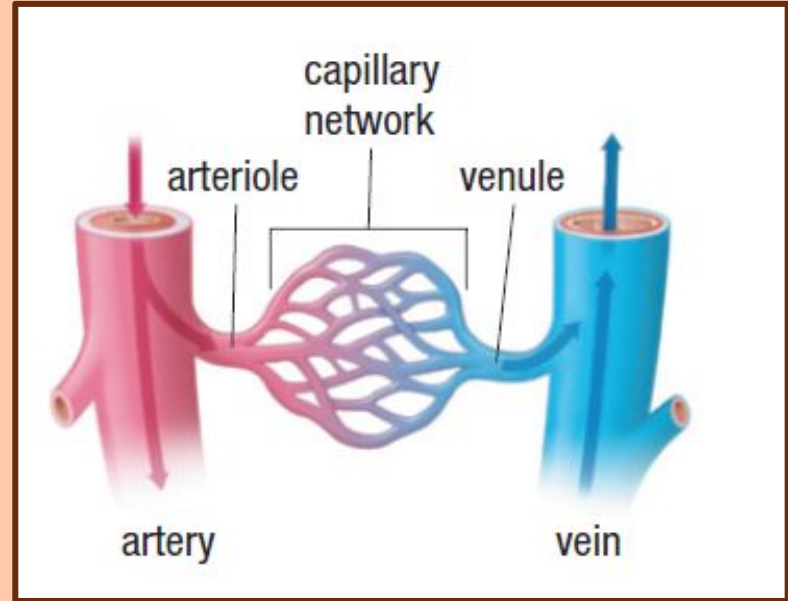
# Comparing Structure of Blood Vessels

<b>Artery</b>	 <p>Thick, elastic wall Endothelium Small lumen Smooth muscle</p>
<b>Vein</b>	 <p>Thin wall Endothelium Large lumen Valve</p>
<b>Capillary</b>	 <p>Very thin wall Endothelium Tiny lumen</p>

# Controlling Blood

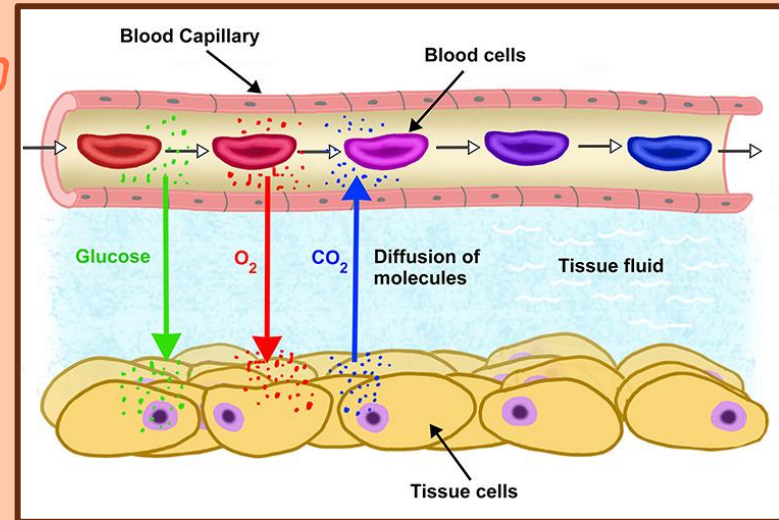
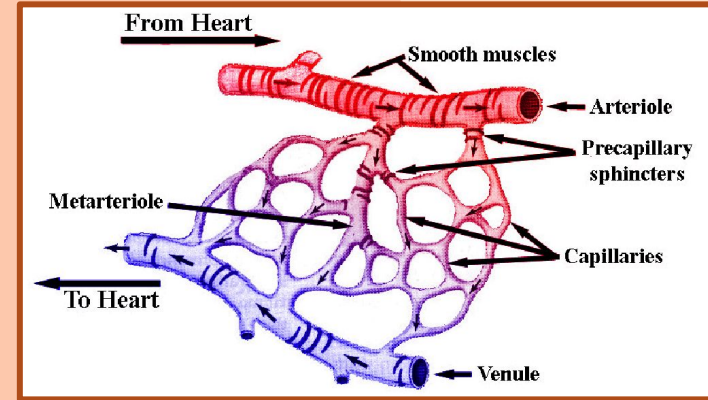


From the arteries into the capillaries. All your organs and muscles become the beneficiaries



# Capillaries

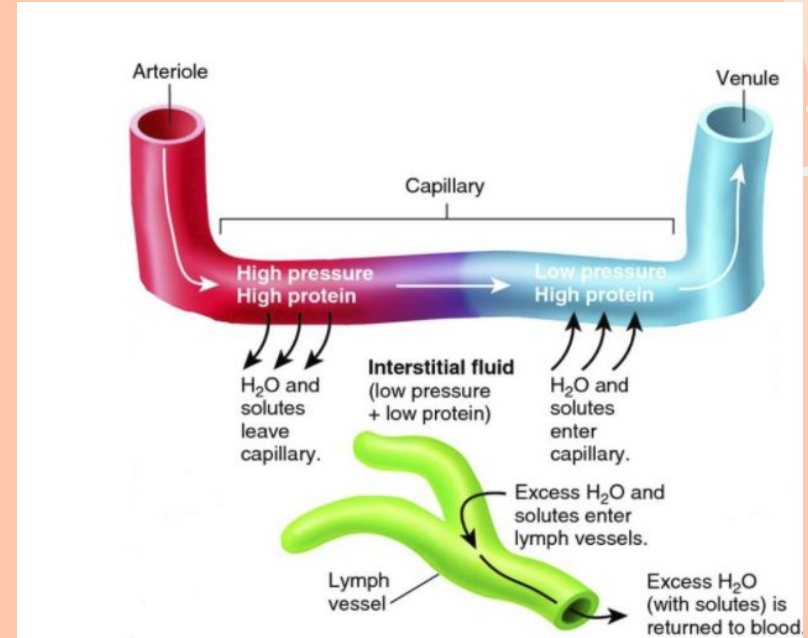
- Capillaries are the **smallest blood vessels**
- No body cell is more than **two cells away** from a capillary
- **Capillary walls** are only **one cell thick**  
(*only a thin endothelial layer with a basal lamina*)  
– **no muscle or connective tissue present**
- **oxygen and nutrients** can diffuse **into fluids** surrounding cells
- **carbon dioxide and wastes** can diffuse into the **capillaries** to be removed



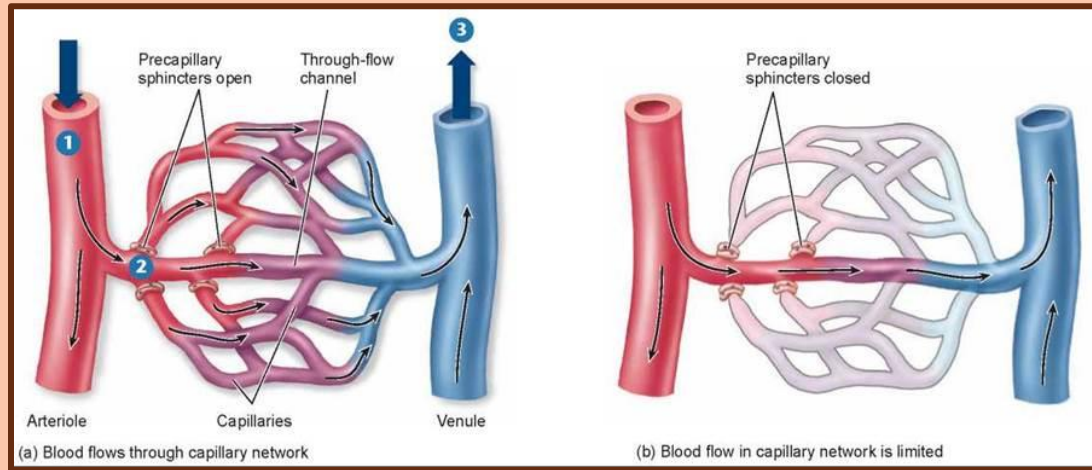
# Capillaries

**Higher fluid pressure** on **arterial side** of capillary network causes **water** to **exit the capillary** and move into the tissue.

The concentration of **solutes** is increased on the venous side of the capillary network (due to **water having exited**) and fluid pressure is lower here. As a result, water travels back into the blood vessel via **osmosis**.



# Controlling Blood Flow in Capillaries: Sphincter Muscles



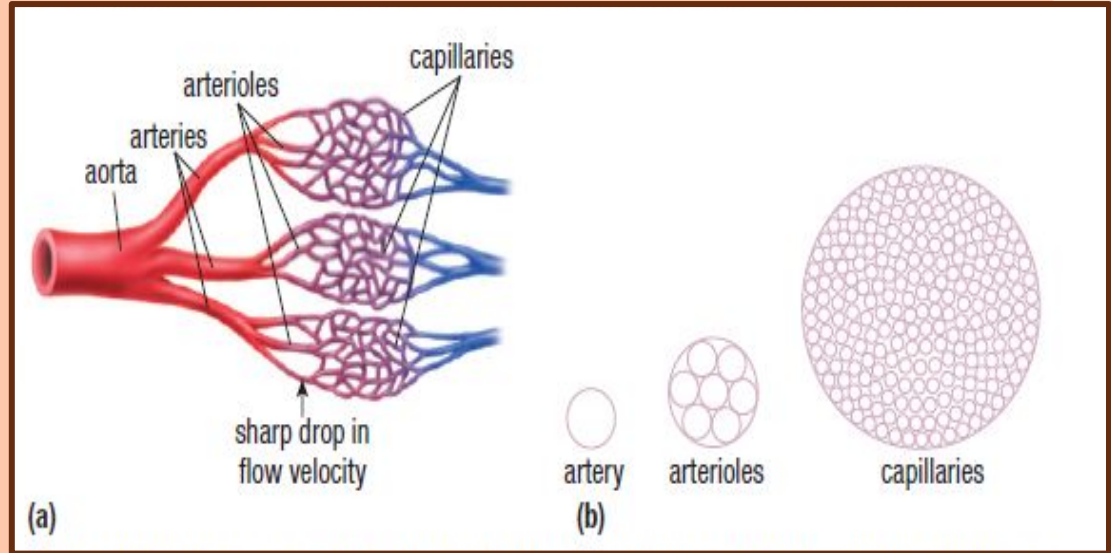
(a) Precapillary sphincter muscles are **relaxed** and blood flow through the capillary network is at a **maximum**.

(b) The sphincter muscles are **contracted**, allowing **minimal** blood flow through the capillary network.



# Controlling Blood Flow in Capillaries

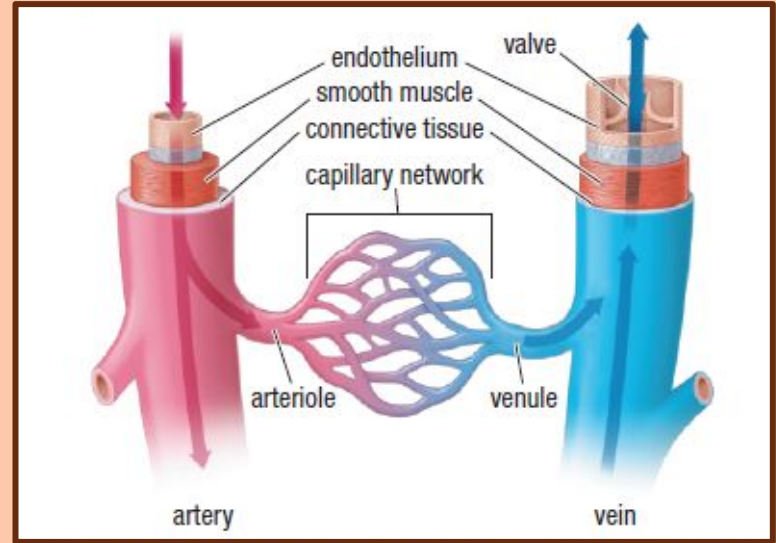
Although capillaries are much **smaller** in diameter than arteries or arterioles, the **cumulative** cross-sectional area of a capillary network is much **greater** than that of even the largest arteries, resulting in a **decrease** in flow velocity.



It is physiologically beneficial to slow the movement of red blood cells through capillaries ... it means more **diffusion** can occur!

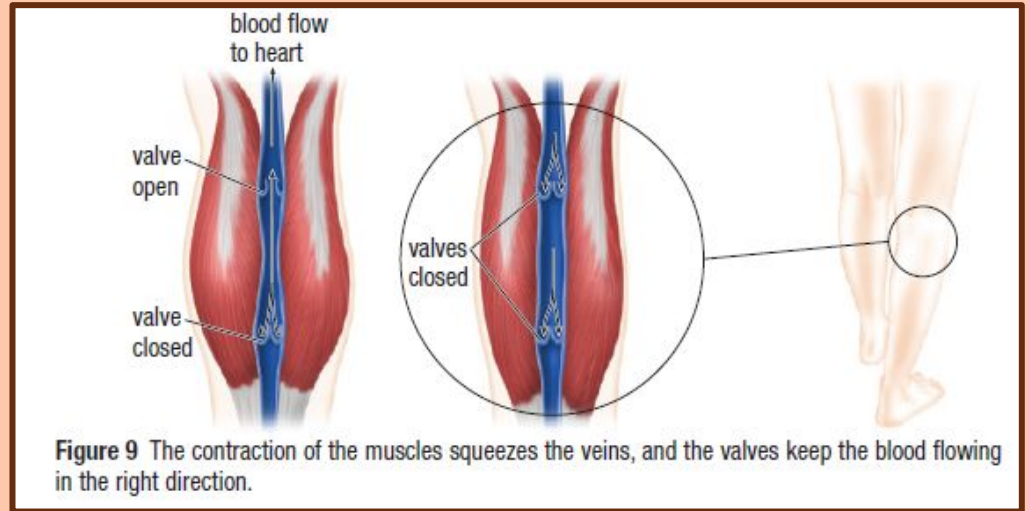
# Venules and Veins

- A **venule** is the **smallest vein**; formed by the **merging** of capillaries
- Venules and veins carry blood from the tissues **back to the heart**



# Venules and Veins

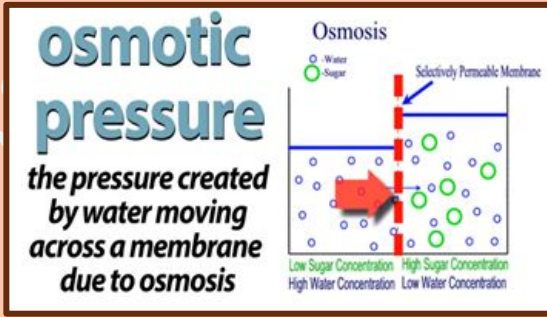
- Veins carry blood at **lower pressure** compared to arteries, and are **thinner walled**
- Veins rely on **one way valves** and **skeletal muscle contractions** to keep blood flowing one-way, back to the heart
  - **Remember:** arteries have pressure from the heart to help move blood through them



# What happens if those valves don't work properly?



# Blood Pressure and Sodium



## Osmotic Pressure

The pressure created by water moving across a membrane due to osmosis

## Osmosis

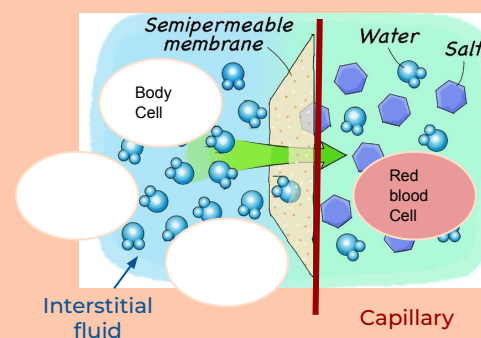
Movement of **water** from an area of high concentration to an area of low concentration without using energy.

A high concentration of **sodium** ions in plasma creates an **osmotic pressure gradient** and causes water to enter the bloodstream from the surrounding cells

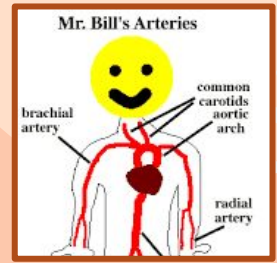
## Hypertension

As more water enters the blood, **blood volume increases**.

Increased blood volume increases pressure exerted on vessel walls - **hypertension** (high blood pressure)



# Blood pressure



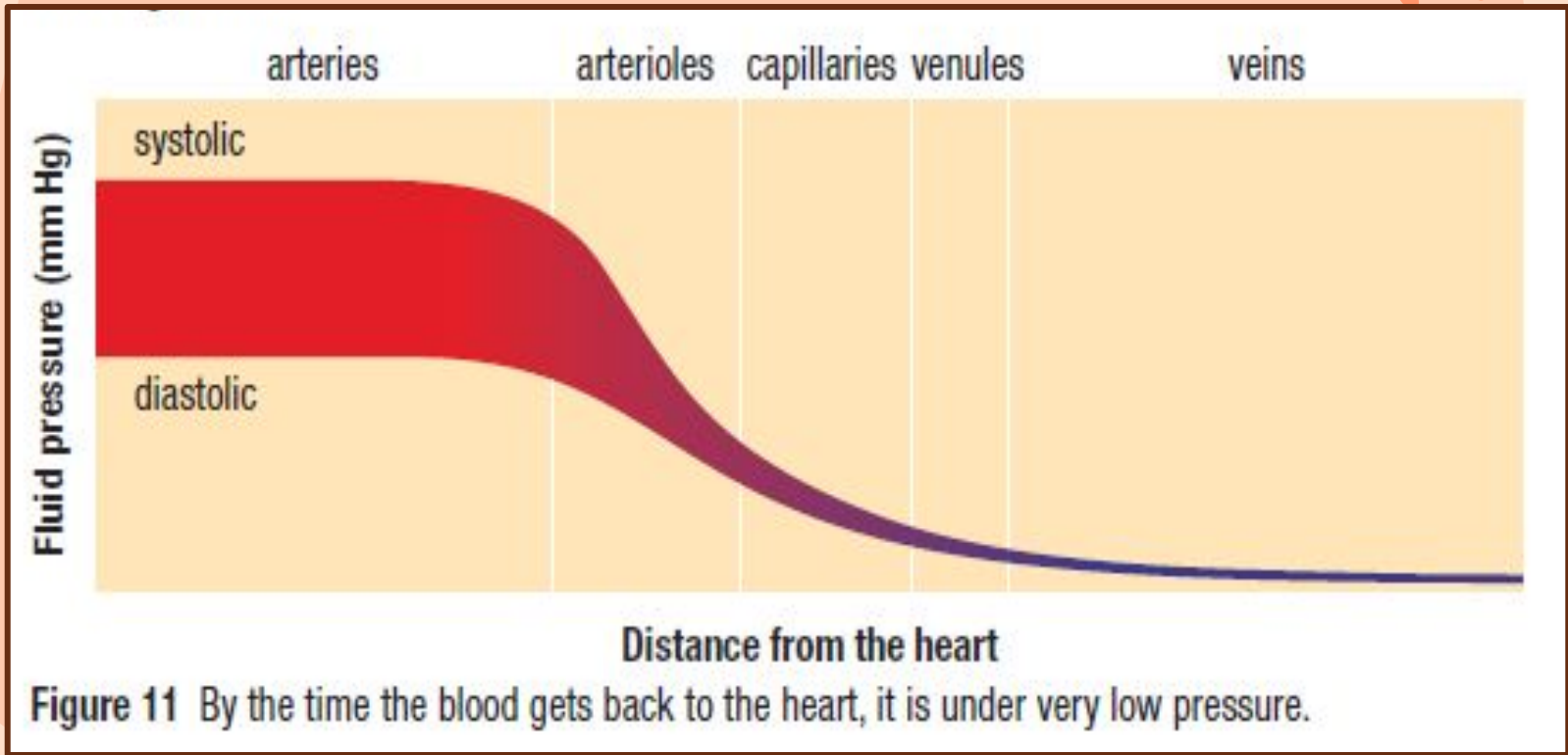
- Blood pressure is measured with a **sphygmomanometer** - an **inflatable cuff** that is wrapped around the arm and a display.
- The cuff is inflated until the **blood flow** in the brachial artery is **stopped**.
- As the **pressure is released** from the cuff, **pressure sensors** in the cuff detect the **vibrations** of the blood flowing through the artery.

# Blood Pressure

- The first reading is the **systolic pressure**, which is caused by the flow of blood in the artery when the heart **contracts**, normally about **120 mm Hg**.
- The second reading is the **diastolic pressure**, which is caused by the flow of blood in the artery when the heart is **relaxed** (between beats). This is normally about **80 mm Hg**.



- Normal blood pressure is reported as 120/80 (read as 120 over 80) and means that the individual has a systolic pressure of 120 mm Hg and a diastolic pressure of 80 mm Hg.

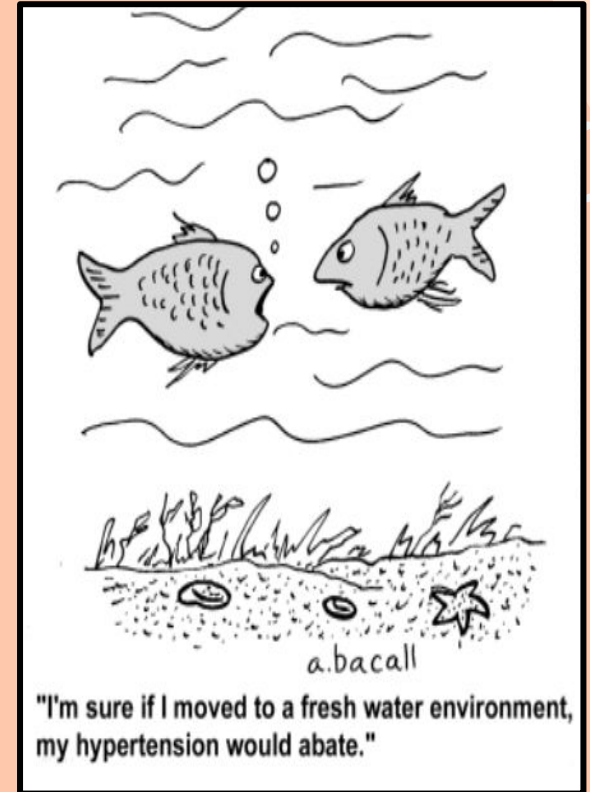


By the time blood returns to the heart it is under very low pressure.



# Hypertension (High Blood Pressure)

- Blood pressures **consistently above** the normal levels constitute a condition called **hypertension**, commonly known as **high blood pressure**.
- Hypertension can be caused by a variety of medical or lifestyle conditions.
  - E.g. kidney disease, genetics and/or high sodium diet



# Hypertension (High Blood Pressure)

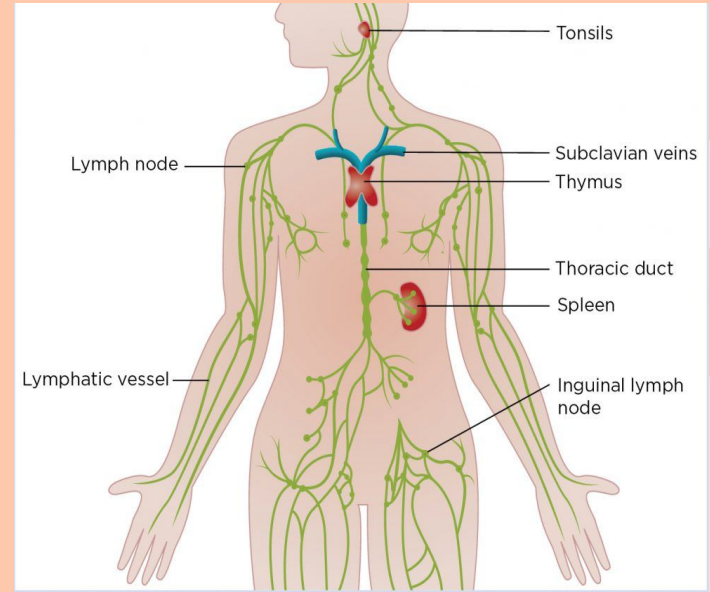
- Often called **“the silent killer”** because it usually does not show any recognizable symptoms until a **serious event**, such as a heart attack or stroke, occurs.
- Hypertension is dangerous because it **forces the heart to work harder** to pump blood around the body.



# Lymphatic System

The lymphatic system is a network of vessels, tissues, and organs that work together to transport lymph, a fluid that contains white blood cells, throughout the body. It is an important part of the **circulatory** and **immune** systems.

- Main functions:
  - Absorption of fats (lacteals)
  - Fluid balance
  - Waste removal
  - Immune defence
  - Transportation of immune cells

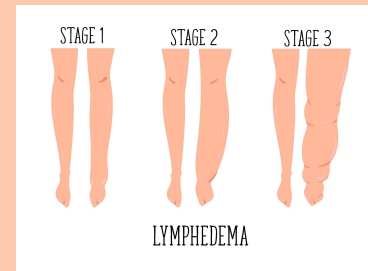
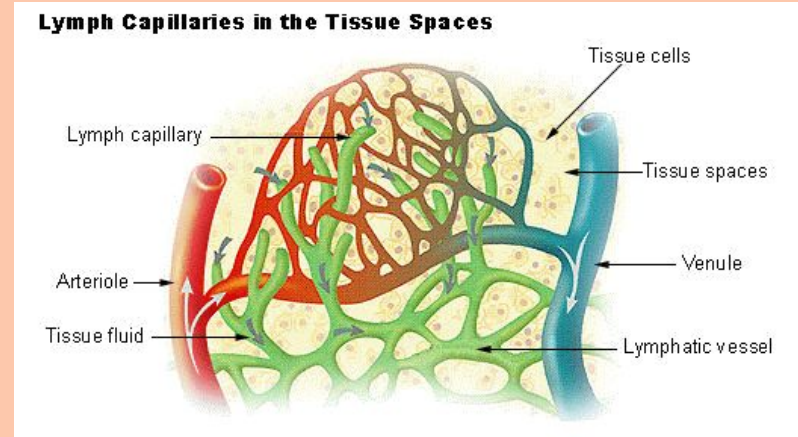


The Major Components of the Lymphatic System

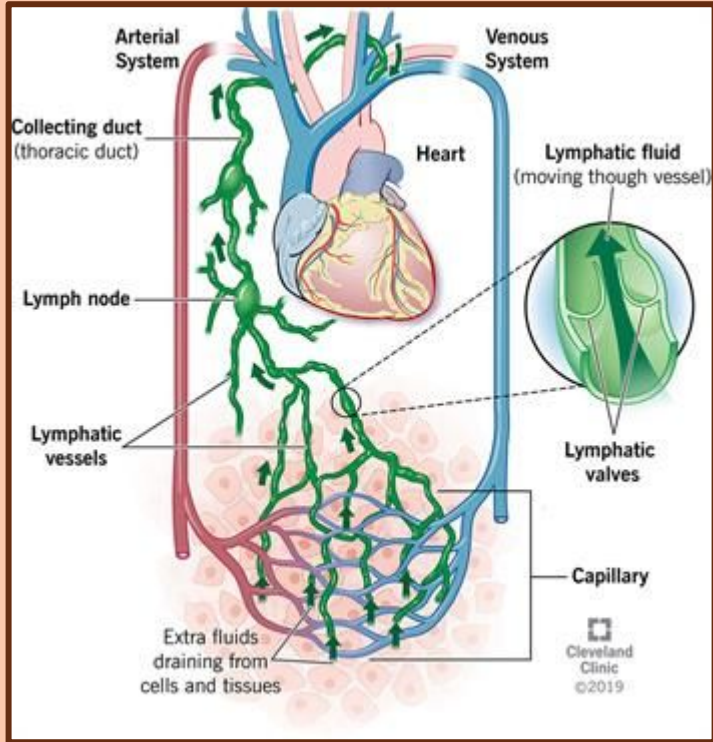
# Lymphatic System & Circulatory System

As part of the **circulatory** system, the lymphatic system helps ensure that the **blood volume** is maintained.

- **Lymph** is tissue fluid collected in lymph vessels and returned to the blood. If not for this system, tissues would swell up (lymphedema).

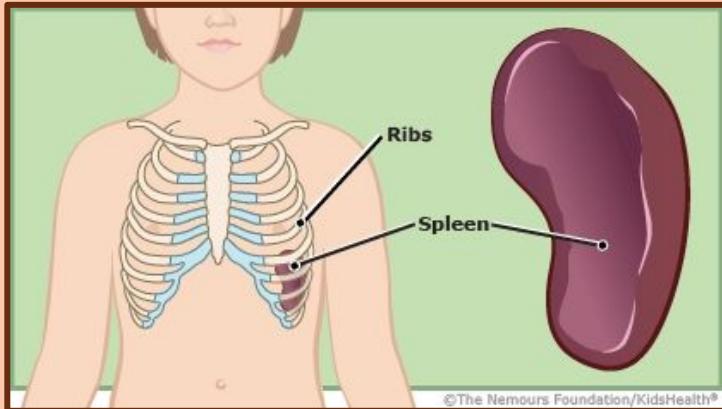
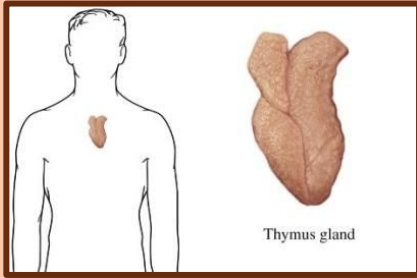


# Lymphatic System & Immune System



- As part of the **immune system**, the lymphatic system **filters** bacteria and other components from the blood
  - A **lymph node** is an enlargement in the **lymph vessels** that acts as a **filter** to remove bacteria and foreign particles; these nodes can sometimes get **swollen when you are sick**

# Lymphatic System & Immune System



- The **thymus** secretes **hormones** that help in the production of **T-lymphocytes**, a type of leukocyte, that helps fight infection
- The **spleen** is the largest organ of the lymphatic system. It acts as a **filter** to remove old and damaged **erythrocytes** and as a **reservoir** of erythrocytes (red blood cells) and leukocytes (white blood cells)

# Homework

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