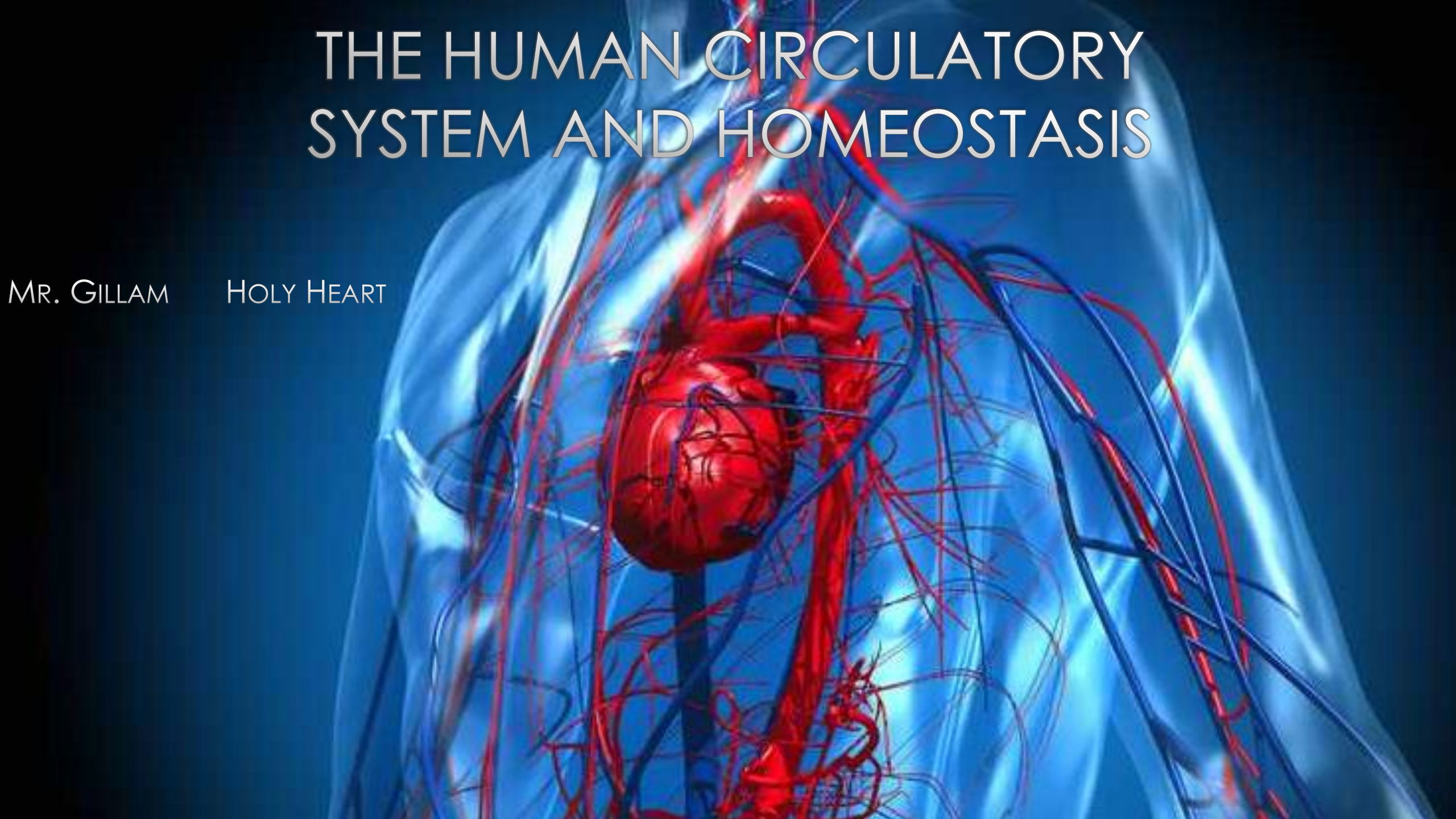
THE HUMAN CIRCULATORY SYSTEM AND HOMEOSTASIS



MR. GILLAM HOLY HEART

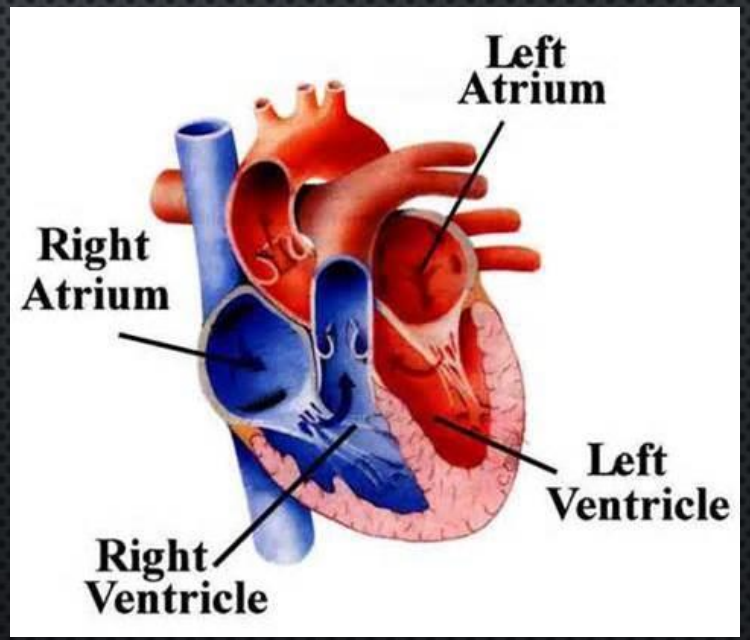
- CIRCULATORY SYSTEM IN ANIMALS, THE SYSTEM OF VESSELS THAT TRANSPORTS BLOOD, CELLS AND SUBSTANCES DISSOLVED IN BLOOD THROUGHOUT THE BODY.

MAIN FUNCTIONS OF THE CIRCULATORY SYSTEM

- THE CIRCULATORY SYSTEM HAS THREE MAIN FUNCTIONS, ALL OF WHICH HELP MAINTAIN HOMEOSTASIS IN THE BODY:
- 1. THE CIRCULATORY SYSTEM TRANSPORTS GASES (FROM THE RESPIRATORY SYSTEM), NUTRIENT MOLECULES (FROM THE DIGESTIVE SYSTEM), AND WASTE MATERIALS (FROM THE EXCRETORY SYSTEM).
- 2. THE CIRCULATORY SYSTEM REGULATES INTERNAL TEMPERATURE AND TRANSPORTS HORMONES. MUCH OF THE BODY'S HEAT IS GENERATED BY THE MUSCULAR SYSTEM. HORMONES ARE REACTION-TRIGGERING CHEMICALS THAT ARE PRODUCED BY THE ENDOCRINE SYSTEM. GASTRIN, SECRETIN, AND CCK ARE INVOLVED IN REGULATING DIGESTION.
- 3. THE CIRCULATORY SYSTEM PROTECTS AGAINST BLOOD LOSS FROM INJURY AND AGAINST DISEASE-CAUSING MICROBES OR TOXIC SUBSTANCES INTRODUCED INTO THE BODY

Structures of the Circulatory System

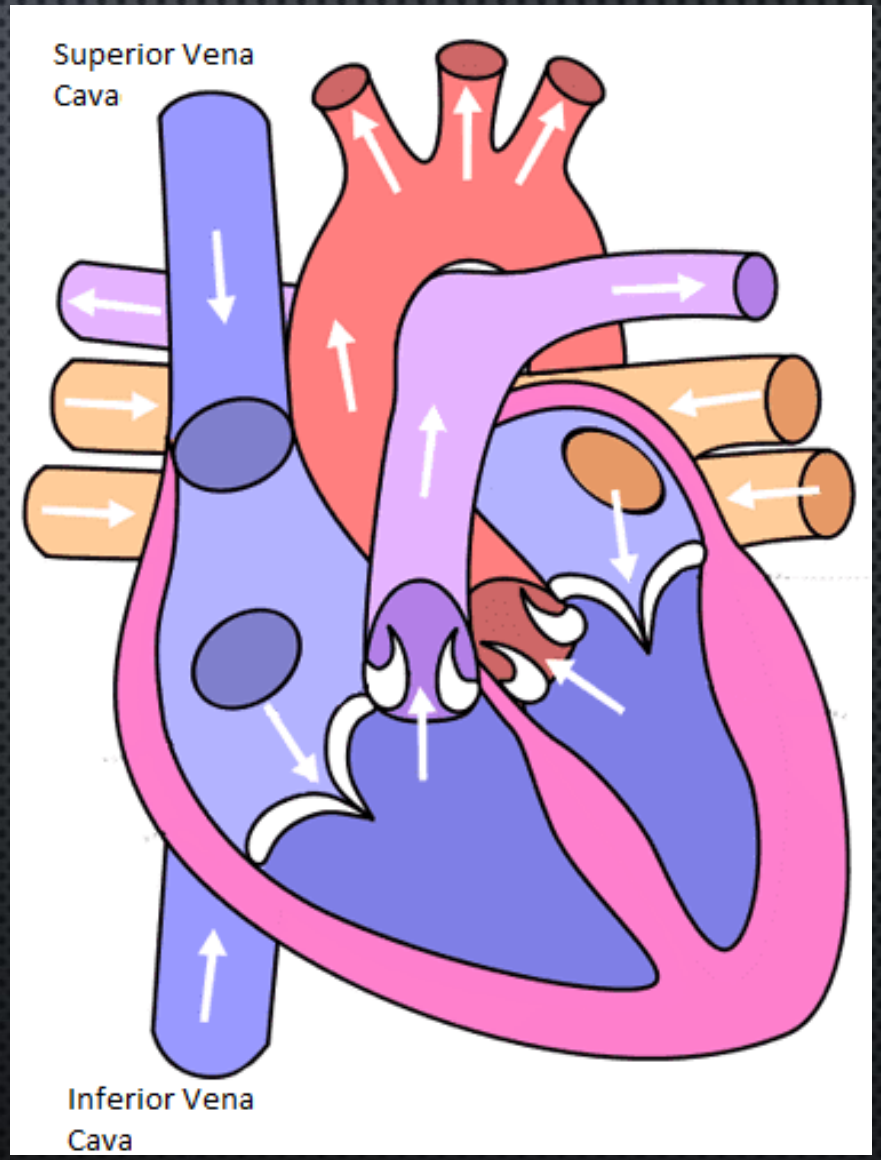
- The Human Heart Located slightly to the left of the middle of the chest, the heart has several important functions. These functions include pumping blood through the body, keeping oxygen-rich blood separate from oxygen-poor blood, and ensuring that blood flows only in one direction through the body. The walls of the heart are made up of a special type of muscle tissue, called cardiac muscle, that is found nowhere else in the body. It is about the size of your fist as a child and the size of two fists as an adult.
- The human heart, like the hearts of all mammals and birds, has four chambers: one top chamber and one bottom chamber on both the right and left sides.



THE HEART

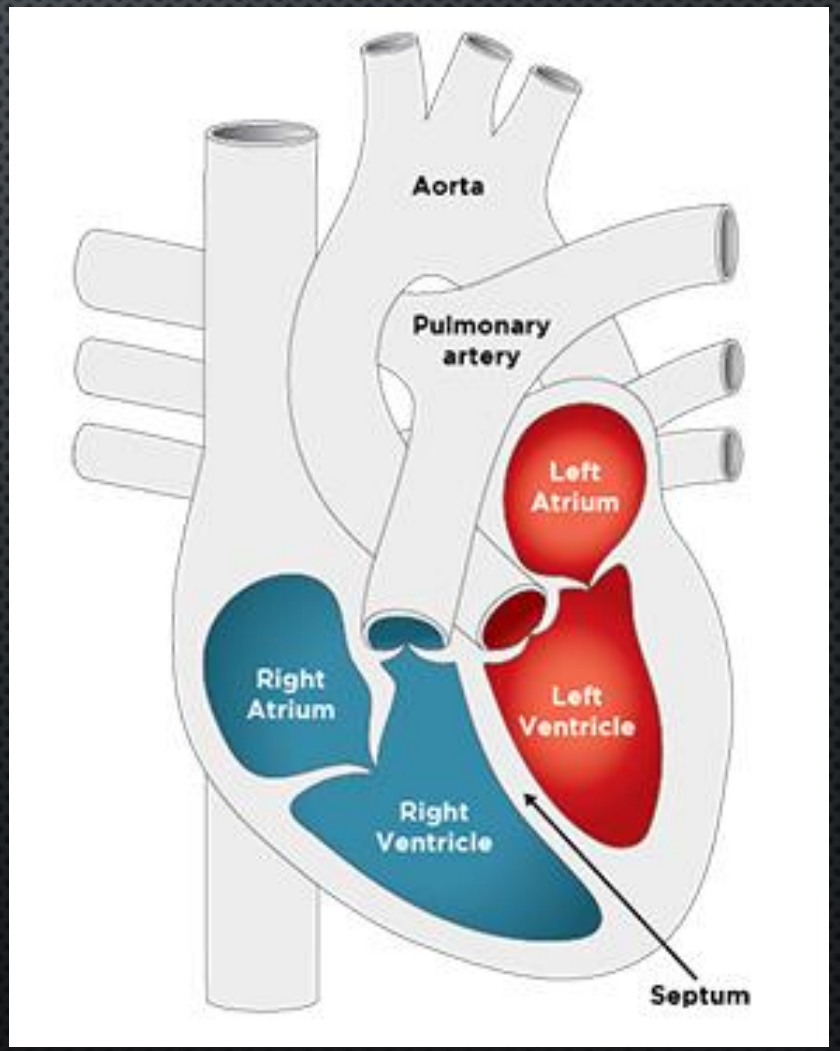
- VENA CAVA ONE OF TWO LARGE VESSELS, THE SUPERIOR AND INFERIOR VENA CAVA, THAT OPEN INTO THE RIGHT ATRIUM OF THE HEART.

- THE SUPERIOR VENA CAVA COLLECTS OXYGEN-POOR BLOOD COMING FROM THE TISSUES IN THE HEAD, CHEST, AND ARMS. THE INFERIOR VENA CAVA COLLECTS OXYGEN-POOR BLOOD COMING FROM THE TISSUES ELSEWHERE IN THE BODY.



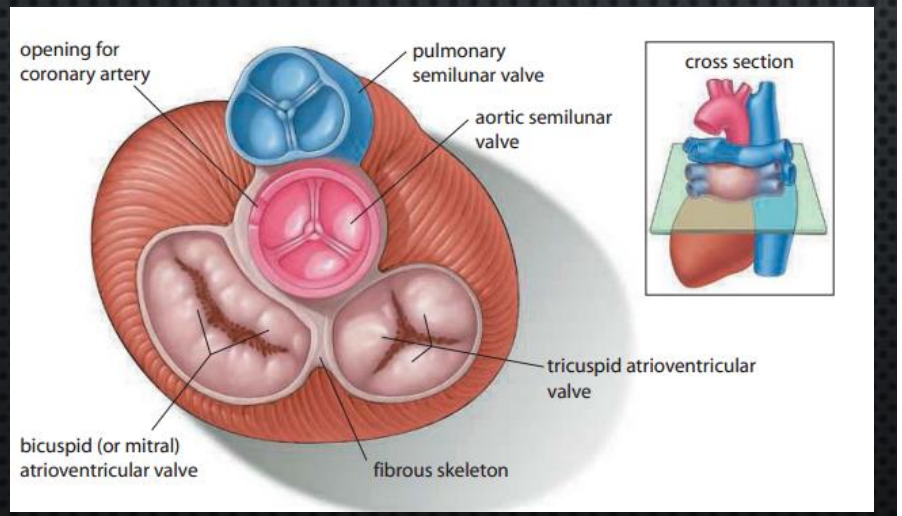
THE HEART

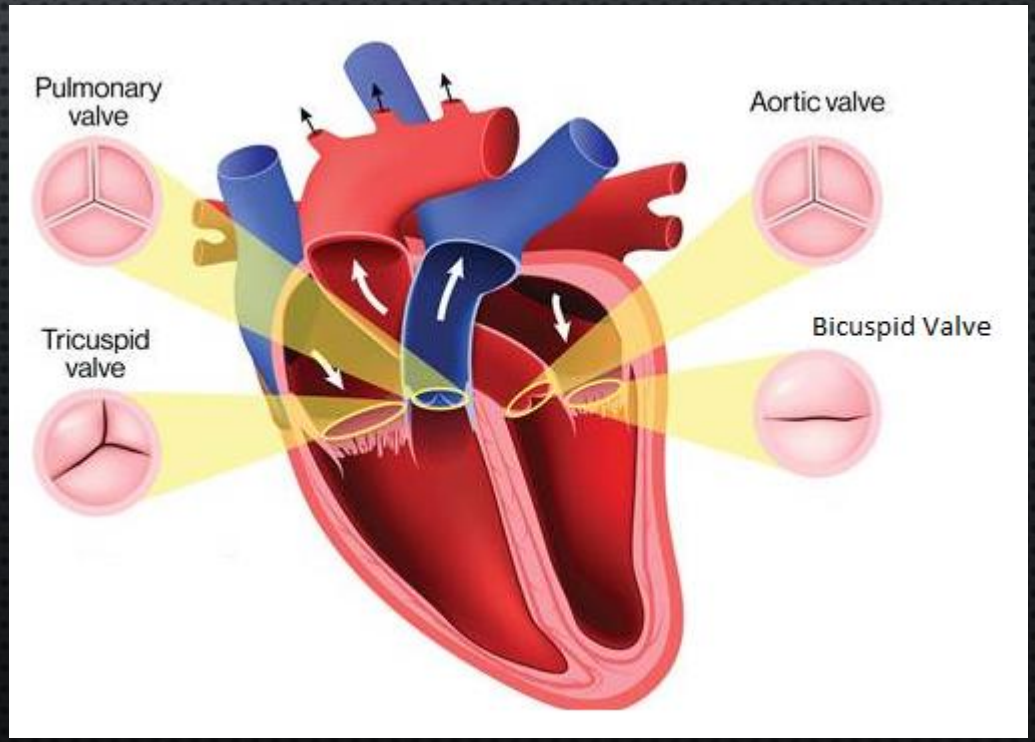
- ATRIUM ONE OF TWO UPPER CHAMBERS OF THE HEART THAT COLLECTS BLOOD LOWING INTO THE HEART.
- VENTRICLE ONE OF THE TWO LOWER CHAMBERS OF THE HEART; EACH VENTRICLE RECEIVES BLOOD FROM ONE OF THE ATRIA AND PUMPS IT INTO SYSTEMIC OR PULMONARY CIRCULATION
- SEPTUM IN THE HEART, THE MUSCULAR WALL THAT SEPARATES THE TWO VENTRICLES AND THE TWO ATRIA. IT STOPS OXYGENATED AND DEOXYGENATED BLOOD FROM MIXING.



THE HEART

- VALVE MEMBRANOUS EXTENSION OF A VESSEL OR THE HEART WALL THAT OPENS AND CLOSES, ENSURING ONE-WAY FLUID FLOW. THE HEART HAS FOUR VALVES INSIDE IT.
- THE ATRIA AND VENTRICLES ARE SEPARATED FROM EACH OTHER BY TWO VALVES CALLED THE ATRIOVENTRICULAR VALVES. THE ATRIOVENTRICULAR VALVE ON THE RIGHT SIDE IS CALLED THE TRICUSPID VALVE BECAUSE IT IS MADE UP OF THREE FLAPS. THE ATRIOVENTRICULAR VALVE ON THE LEFT SIDE IS CALLED THE BICUSPID VALVE BECAUSE IT HAS ONLY TWO FLAPS. THE OTHER TWO VALVES ARE CALLED SEMILUNAR VALVES BECAUSE OF THEIR HALF-MOON SHAPE.

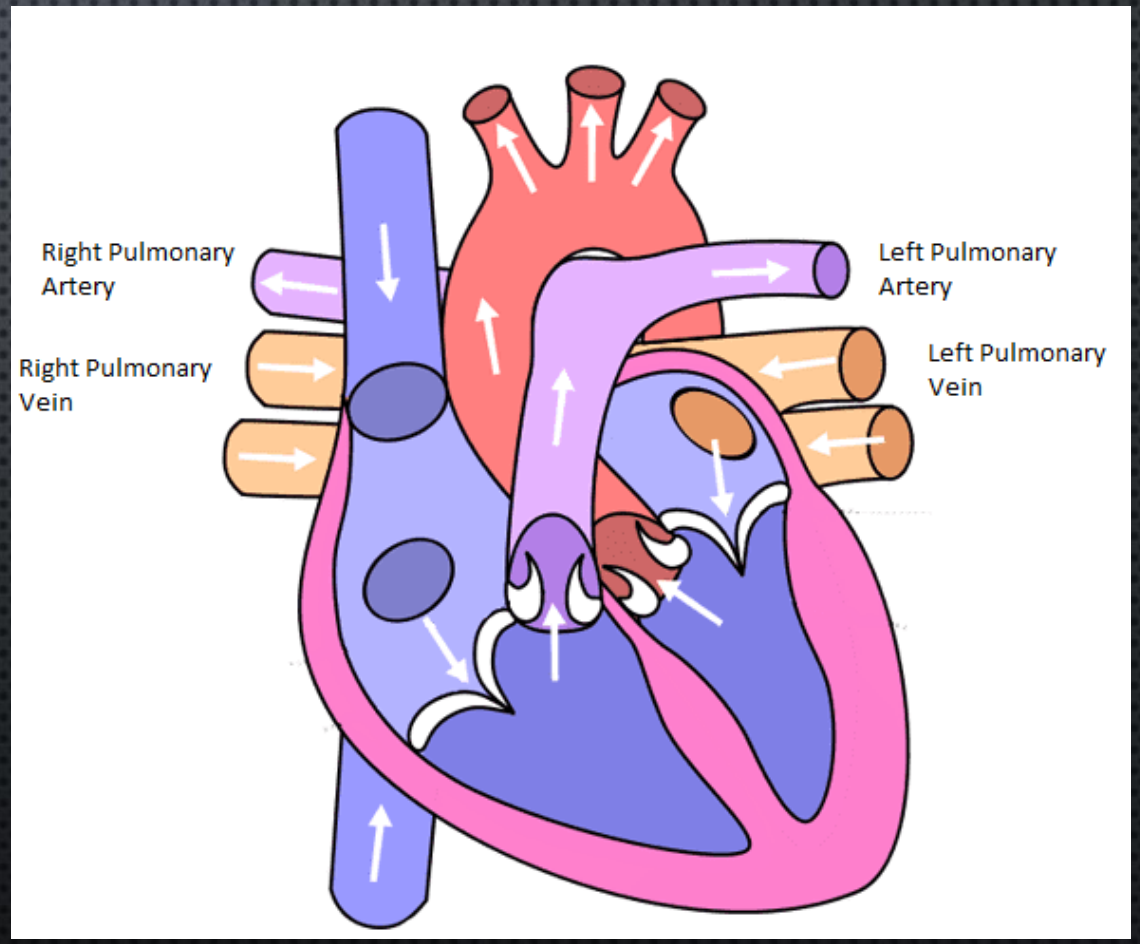




THE HEART

- PULMONARY ARTERY BLOOD VESSEL THAT CARRIES BLOOD FROM THE HEART TO THE LUNGS. THESE ARE THE ONLY ARTERIES IN THE CIRCULATORY SYSTEM THAT CONTAIN OXYGEN-POOR BLOOD.

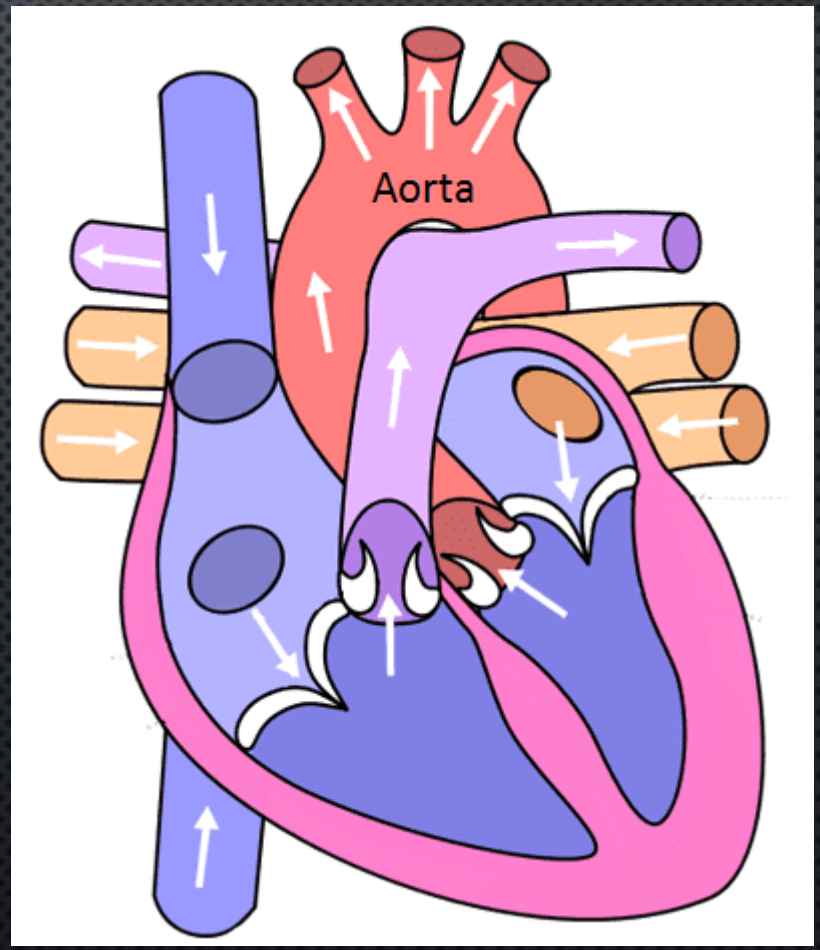
- PULMONARY VEIN BLOOD VESSEL THAT CARRIES BLOOD FROM THE LUNGS TO THE HEART. THESE ARE THE ONLY VEINS IN THE CIRCULATORY SYSTEM THAT CONTAIN OXYGENATED BLOOD.



THE HEART

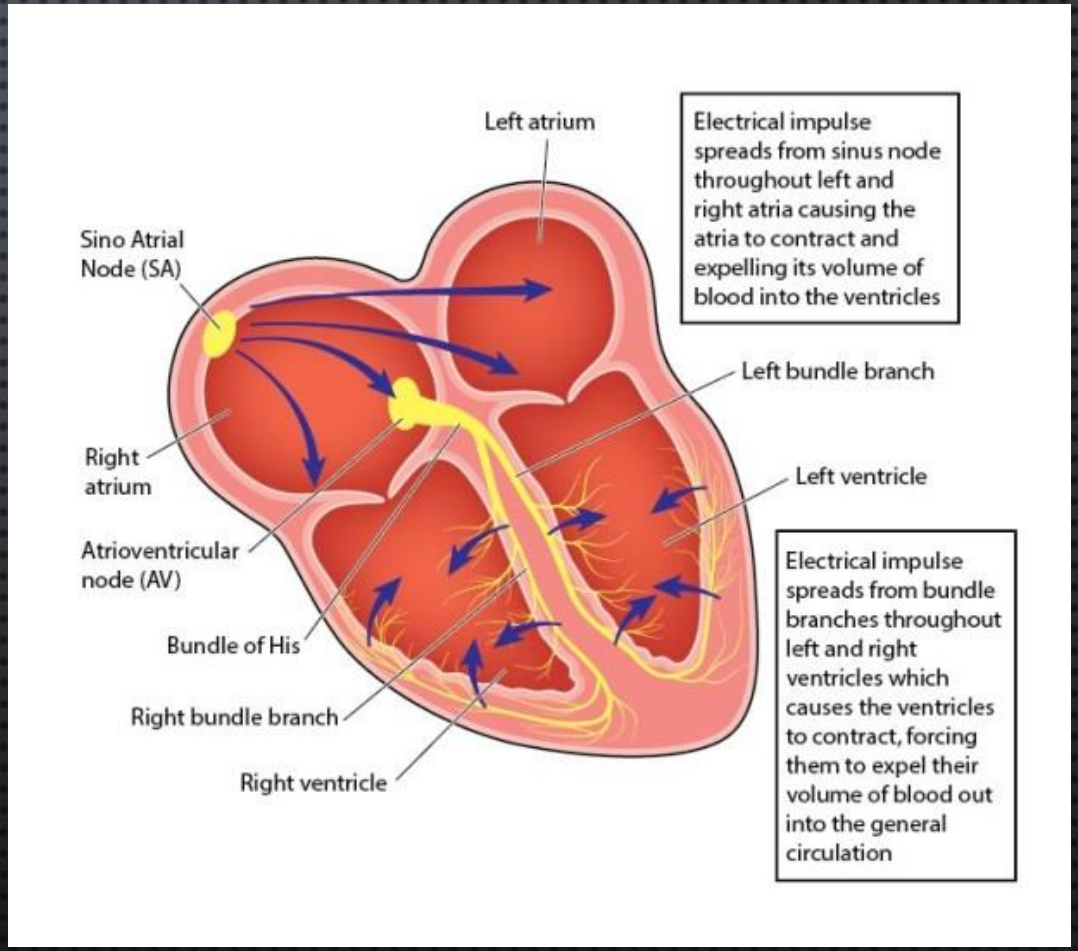
- AORTA MAJOR ARTERY THAT CARRIES OXYGENATED BLOOD AWAY FROM THE HEART TO ALL REGIONS OF THE BODY EXCEPT THE LUNGS.

- THE LARGEST BLOOD VESSEL IN THE BODY.



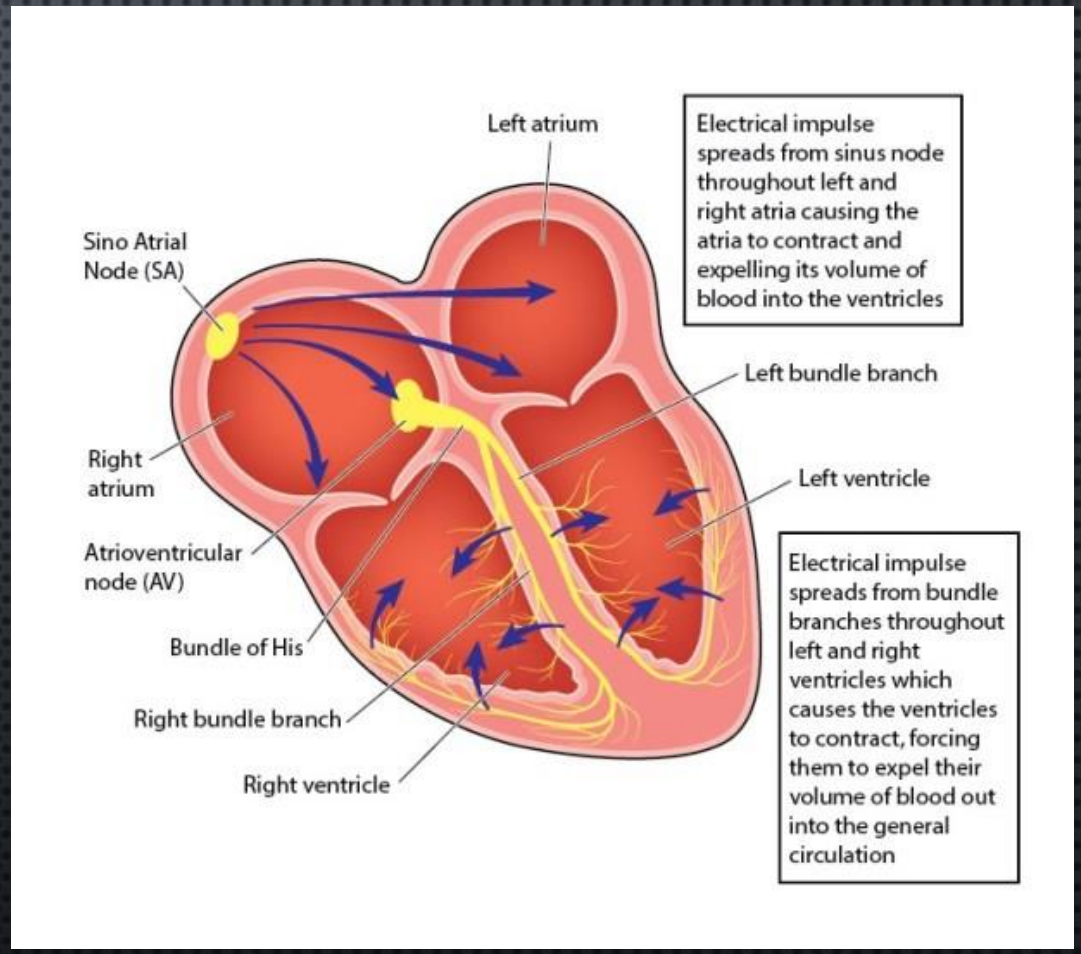
THE HEART

- SINOATRIAL (SA) NODE BUNDLE OF SPECIALIZED MUSCLE TISSUE LOCATED IN THE WALL OF THE RIGHT ATRIUM OF THE MAMMALIAN HEART; GENERATES AN ELECTRICAL IMPULSE THAT STIMULATES CARDIAC MUSCLE FIBRES TO CONTRACT AND RELAX RHYTHMICALLY, PRODUCING A REGULAR HEARTBEAT
- THE SA NODE IS ALSO REFERRED TO AS THE PACEMAKER, BECAUSE IT SETS THE PACE FOR CARDIAC ACTIVITY.



THE HEART

- ATRIOVENTRICULAR (AV) NODE
  BUNDLE OF SPECIALIZED MUSCLE TISSUE LOCATED IN THE WALL OF THE RIGHT ATRIUM; RECEIVES ELECTRICAL STIMULUS FROM THE SINOATRIAL NODE AND TRANSMITS THIS IMPULSE OVER THE WALLS OF THE VENTRICLES TO START THEIR CONTRACTION



PUMPING OF THE HEART

1) The SA node generates an electrical signal that spreads over the two atria and makes them contract simultaneously.

2) As the atria contract, the signal reaches another node called the atrioventricular (AV) node.

3) The AV node transmits the electrical signal through a bundle of specialized fibres called the *bundle of His*.

4) The *Bundle of His relays* the signal through two bundle branches that divide into fast-conducting Purkinje fibres, which initiate the almost simultaneous contraction of all cells of the right and left ventricles.

PUMPING OF THE HEART

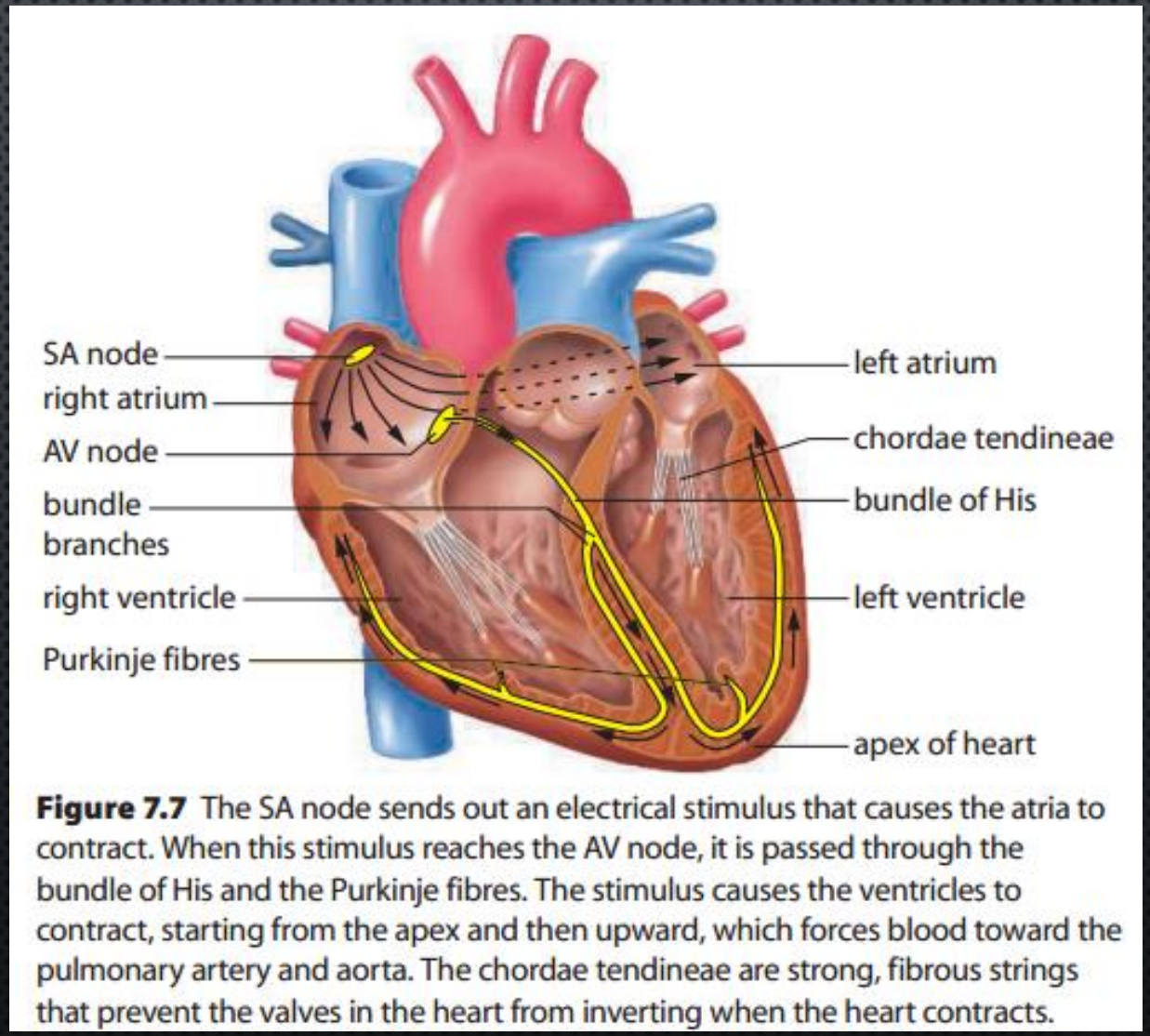
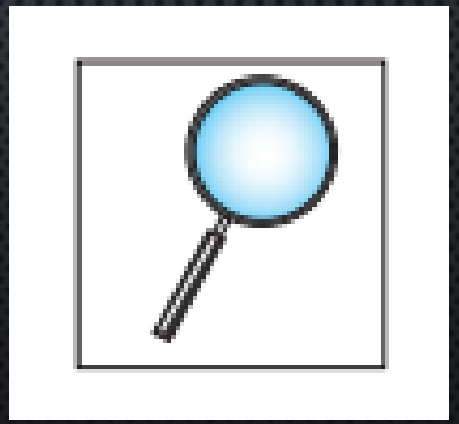


Figure 7.7 The SA node sends out an electrical stimulus that causes the atria to contract. When this stimulus reaches the AV node, it is passed through the bundle of His and the Purkinje fibres. The stimulus causes the ventricles to contract, starting from the apex and then upward, which forces blood toward the pulmonary artery and aorta. The chordae tendineae are strong, fibrous strings that prevent the valves in the heart from inverting when the heart contracts.

PUMPING OF THE HEART

LAUNCH LAB: LISTEN TO YOUR HEART

INVESTIGATION 7A IDENTIFYING STRUCTURES OF THE CIRCULATORY SYSTEM



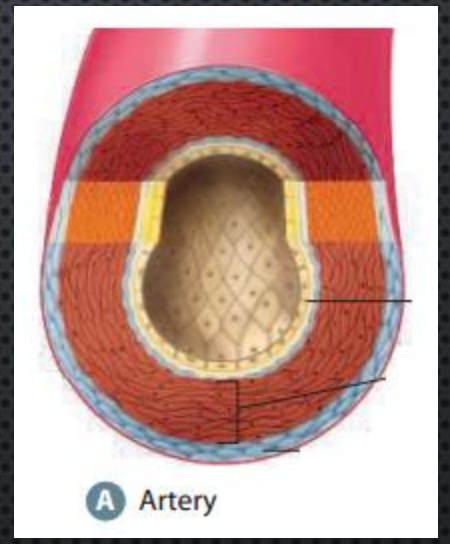
STRUCTURES OF THE CIRCULATORY SYSTEM

ARTERY BLOOD VESSEL THAT CARRIES OXYGEN-RICH BLOOD AWAY FROM THE HEART

AN ARTERY HAS HIGHLY ELASTIC WALLS. THIS ELASTICITY ALLOWS THE ARTERY TO EXPAND AS A WAVE OF BLOOD SURGES THROUGH IT DURING THE CONTRACTION OF THE VENTRICLES, AND THEN TO SNAP BACK AGAIN DURING THE RELAXATION OF THE VENTRICLES.

THE ACTION OF THE ARTERY KEEPS THE BLOOD FLOWING IN THE RIGHT DIRECTION AND PROVIDES AN ADDITIONAL PUMPING MOTION TO HELP FORCE THE BLOOD THROUGH THE BLOOD VESSELS.

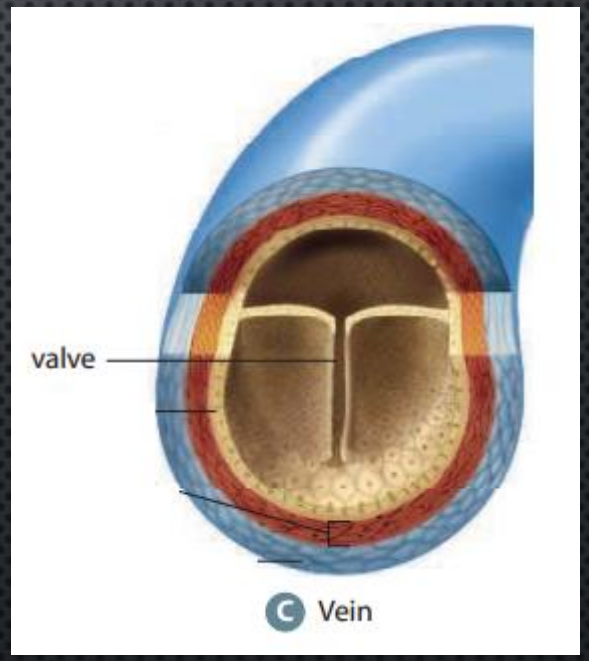
WHEN YOU MEASURE YOUR PULSE, WHAT YOU FEEL IS THE RHYTHMIC EXPANSION AND CONTRACTION OF AN ARTERY AS BLOOD MOVES THROUGH IT.



STRUCTURES OF THE CIRCULATORY SYSTEM

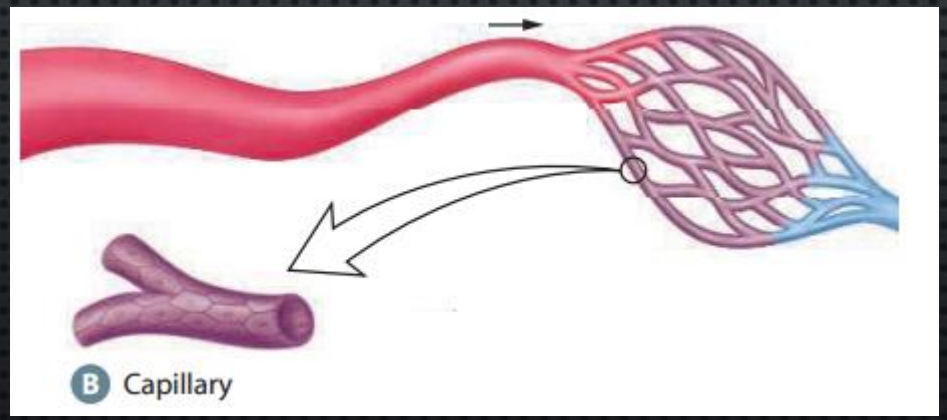
VEIN BLOOD VESSEL THAT CARRIES OXYGEN-POOR BLOOD TO THE HEART

VEINS HAVE THINNER WALLS THAN ARTERIES AND A LARGER INNER CIRCUMFERENCE. VEINS ARE NOT AS ELASTIC, AND THEY CANNOT CONTRACT TO HELP MOVE THE BLOOD BACK TO THE HEART. INSTEAD, THE CONTRACTION OF MUSCLES KEEPS THE BLOOD FLOWING TOWARD THE HEART. VEINS ALSO HAVE ONE-WAY VALVES THAT PREVENT THE BLOOD FROM FLOWING BACKWARD. THESE ONE-WAY VALVES ARE ESPECIALLY IMPORTANT IN YOUR LEGS BECAUSE THEY ENSURE THAT THE BLOOD FLOWS UPWARD TO YOUR HEART, AGAINST THE DOWNWARD PULL OF GRAVITY.



STRUCTURES OF THE CIRCULATORY SYSTEM

CAPILLARY THE SMALLEST BLOOD VESSEL; GASES AND OTHER SUBSTANCES ARE EXCHANGED BETWEEN THE CIRCULATORY SYSTEM AND BODY TISSUES ACROSS THE CAPILLARY WALL, WHICH IS ONLY A SINGLE CELL THICK



STRUCTURES OF THE CIRCULATORY SYSTEM

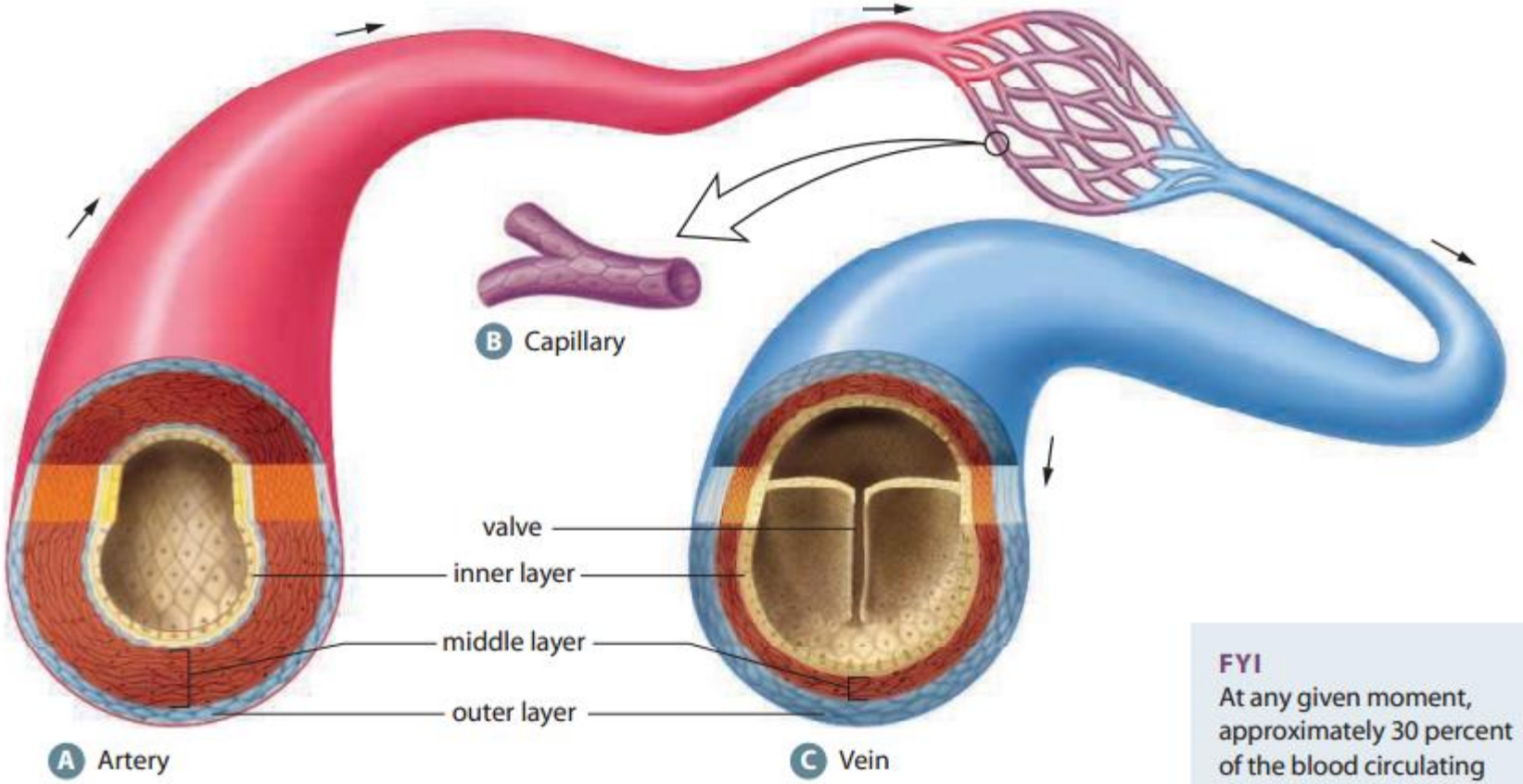


Figure 7.4 Arteries **(A)** and veins **(C)** have three layers. The outer layer is a covering of connective tissue mixed with elastic tissue. The middle layer consists of alternating, circular bands of elastic tissue and smooth muscle tissue. The inner layer is only one cell thick and consists of flat, smooth cells. The shape and texture of these cells serve to reduce friction as blood moves through them. Capillaries **(B)** consist of a single layer that is one cell thick.

FYI

At any given moment, approximately 30 percent of the blood circulating through your body is found in the arteries, 5 percent is found in the capillaries, and 65 percent is found in the veins.

CIRCULATION AND THE ACTION OF CAPILLARIES

THE CELLS OF THE BODY ARE CONSTANTLY BATHED IN A LIQUID CALLED INTERSTITIAL FLUID (EXTRACELLULAR FLUID OR TISSUE FLUID). ANY MATERIAL EXCHANGED BETWEEN THE CAPILLARIES AND THE CELLS MUST PASS THROUGH THE INTERSTITIAL FLUID.

CAPILLARIES HAVE AN ARTERIAL END, A MID-SECTION, AND A VENOUS END.

WHEN BLOOD ENTERS A CAPILLARY AT THE ARTERIAL END, IT APPEARS TO BE BRIGHT RED BECAUSE THE HEMOGLOBIN IN THE RED BLOOD CELLS IS RICH IN OXYGEN.

THE DIFFUSION OF MATERIALS, INCLUDING THE OXYGEN ATTACHED TO THE HEMOGLOBIN IN RED BLOOD CELLS AND THE NUTRIENTS SUSPENDED IN THE BLOOD'S PLASMA, TAKES PLACE ALONG THE MID-SECTION OF A CAPILLARY.

THE DIRECTION OF DIFFUSION IS DETERMINED BY A MATERIAL'S CONCENTRATION GRADIENT. FOR EXAMPLE, NUTRIENTS AND OXYGEN ARE HIGHER IN CONCENTRATION IN THE BLOOD, SO THEY DIFFUSE INTO THE INTERSTITIAL FLUID TOWARD THE CELLS.

CARBON DIOXIDE AND OTHER WASTES ARE HIGHER IN CONCENTRATION IN THE INTERSTITIAL FLUID, SO THEY DIFFUSE OUT OF THE CELLS THROUGH THE INTERSTITIAL FLUID AND INTO THE CAPILLARIES.

CIRCULATION

CORONARY PATHWAY THE CIRCULATORY PATHWAY THAT SUPPLIES OXYGEN-RICH BLOOD TO AND CARRIES DEOXYGENATED BLOOD FROM THE MUSCLE TISSUE OF THE HEART

PULMONARY PATHWAY THE CIRCULATORY PATHWAY THAT CARRIES OXYGEN-POOR BLOOD FROM THE HEART TO THE LUNGS AND OXYGEN-RICH BLOOD FROM THE LUNGS TO THE HEART

SYSTEMIC PATHWAY THE CIRCULATORY PATHWAY THAT CARRIES OXYGEN-RICH BLOOD FROM THE HEART TO THE BODY TISSUES, AND OXYGEN-POOR BLOOD FROM THE TISSUES BACK TO THE HEART

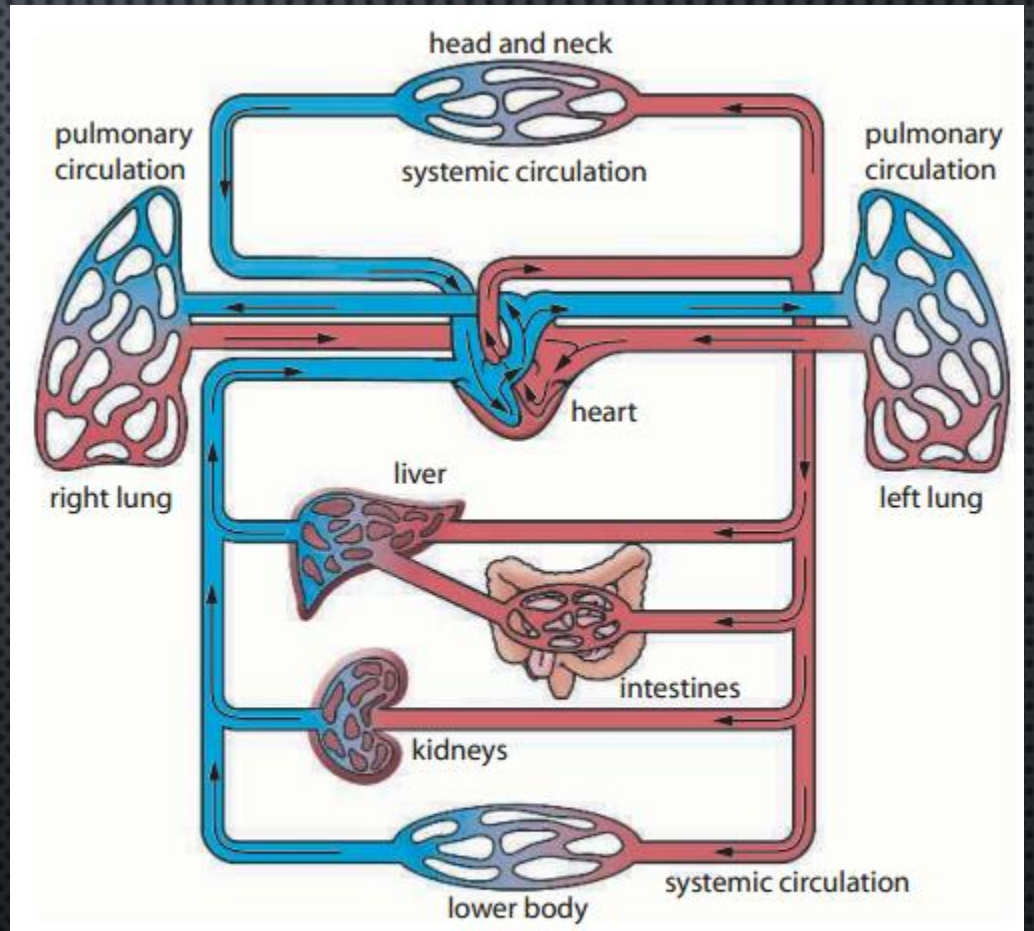


Figure 7.9 Trace the flow of blood through the pulmonary and systemic pathways. Arteries carry blood away from the heart; veins carry blood toward it. Note that in the systemic pathway, arteries carry oxygen-rich blood (red) and veins carry oxygen-poor blood (blue). The reverse is true in the pulmonary pathway: arteries carry oxygen-poor blood and veins carry oxygen-rich blood.

CIRCULATION PATHWAY

1) The superior/inferior vena cava collect oxygen-poor blood coming from the tissues and dumps it into the right atrium.

2) The blood then flows from the right atrium into the right ventricle through the tricuspid valve.

3) Next, it leaves the right ventricle through the pulmonary semi lunar valve into the pulmonary arteries.

4) From there, it continues to the left and right lungs for gas exchange.

5) oxygen-rich blood from the lungs flows back to the heart through the pulmonary veins to the left atrium.

6) The left atrium pumps blood through the bicuspid valve into the left ventricle,

7) The left ventricle pumps blood through the aortic semilunar valve into the aorta

8) Blood is then dispersed from the aorta to all arteries.

9) It then passes from arteries in to capillaries and then veins before returning to the superior/inferior vena cava.

COMPONENTS OF BLOOD

- PLASMA FLUID PORTION OF THE BLOOD, MADE UP OF WATER, DISSOLVED GASES, PROTEINS, SUGARS, VITAMINS, MINERALS, HORMONES, AND WASTE PRODUCTS
- PLASMA MAKES UP ABOUT 55 PERCENT OF THE BLOOD VOLUME.

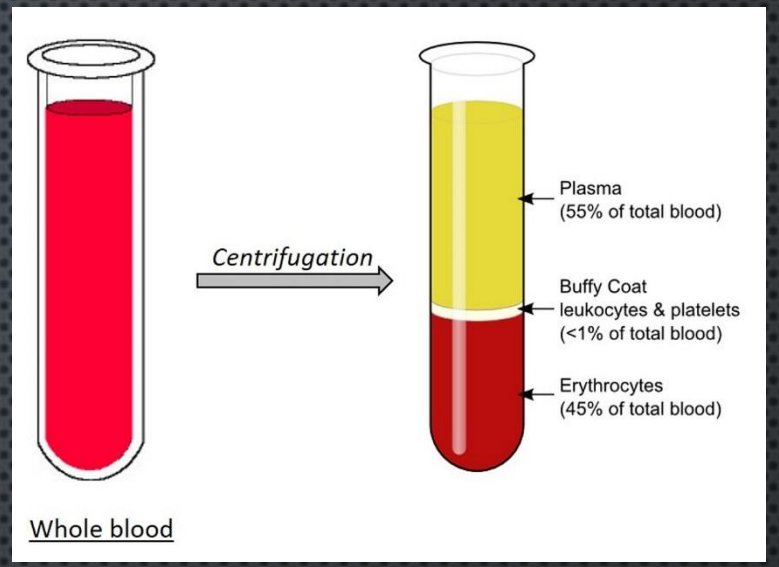


Table 7.3 The Composition of Plasma

Constituent	Percentage
Water	~ 92%
Blood proteins fibrinogen serum albumin serum globulin	~ 7%
Other organic substances non-protein nitrogen (urea) organic nutrients	~ 0.1%
Inorganic ions calcium, chlorine, magnesium, potassium, sodium, bicarbonates, carbonates, phosphates	~ 0.9%

COMPONENTS OF BLOOD

- RED BLOOD CELL(ERYTHROCYTES) BLOOD CELL THAT CONTAINS THE RESPIRATORY PROTEIN HEMOGLOBIN AND IS SPECIALIZED FOR OXYGEN TRANSPORT
- MAKE UP APPROXIMATELY 44 PERCENT OF THE TOTAL VOLUME OF BLOOD.
- A MATURE RED MAMMALIAN BLOOD CELL HAS NO NUCLEUS.
- EACH DISK-SHAPED RED BLOOD CELL IS PACKED WITH ABOUT 280 MILLION IRON-CONTAINING MOLECULES OF THE RESPIRATORY PIGMENT HEMOGLOBIN.

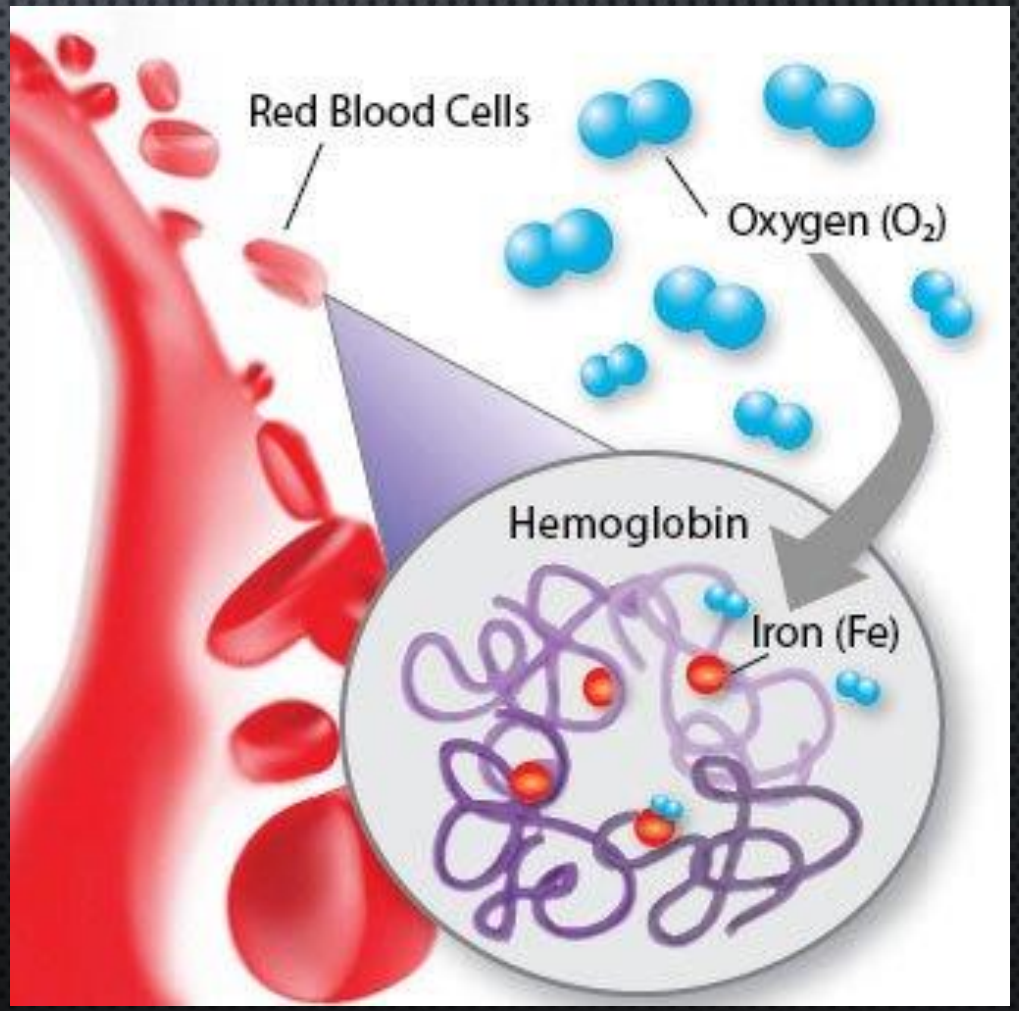
Magnification: 4175 ×

Figure 7.16 A mammalian red blood cell, also known as an erythrocyte, is a biconcave disk. Because the respiratory pigment hemoglobin reflects red wavelengths of light, oxygenated red blood cells appear to be a bright red colour. As oxygen is released, the colour that is reflected is a darker blue-red.

COMPONENTS OF BLOOD

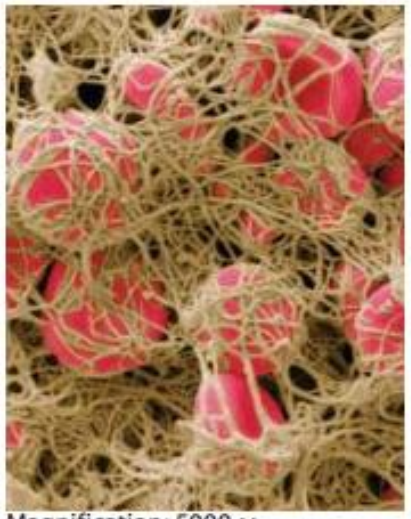
- HEMOGLOBIN IRON-CONTAINING RESPIRATORY PIGMENT FOUND IN RED BLOOD CELLS THAT TRANSPORTS OXYGEN FROM THE LUNGS TO BODY TISSUES

- AFTER CARBON DIOXIDE DIFFUSES INTO THE BLOOD, IT ENTERS THE RED BLOOD CELLS, WHERE A SMALL AMOUNT IS TAKEN UP BY HEMOGLOBIN.



COMPONENTS OF BLOOD

- PLATELET COMPONENT OF THE FORMED PORTION OF THE BLOOD, CONSISTING OF FRAGMENTS OF CELLS THAT ARE CREATED WHEN LARGER CELLS IN THE BONE MARROW BREAK APART; CONTAINS NO NUCLEUS AND PLAYS A KEY ROLE IN BLOOD CLOTTING.



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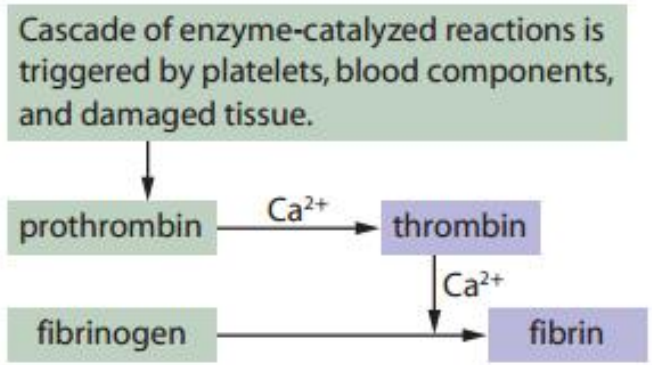


Figure 7.18 Fibrin threads wind around the platelet plug in the damaged area of a blood vessel, providing the framework for a clot.

BLOOD CLOTTING PROCESS AND POSITIVE FEEDBACK

Injury to a blood vessel starts a cascade of cellular events.

1) Substances released by the broken blood vessel attract platelets to the site. As the platelets continue to amass, more of the chemicals are released and more platelets are attracted to the site of the clot.

2) The collecting platelets rupture and release chemicals that combine with other blood components to produce an enzyme called thromboplastin.

3) As long as there are calcium ions (Ca^{2+}) present, thromboplastin will react with prothrombin (a plasma protein produced by the liver) to produce thrombin.

4) Thrombin is an enzyme that reacts with fibrinogen (another plasma protein) to produce fibrin.

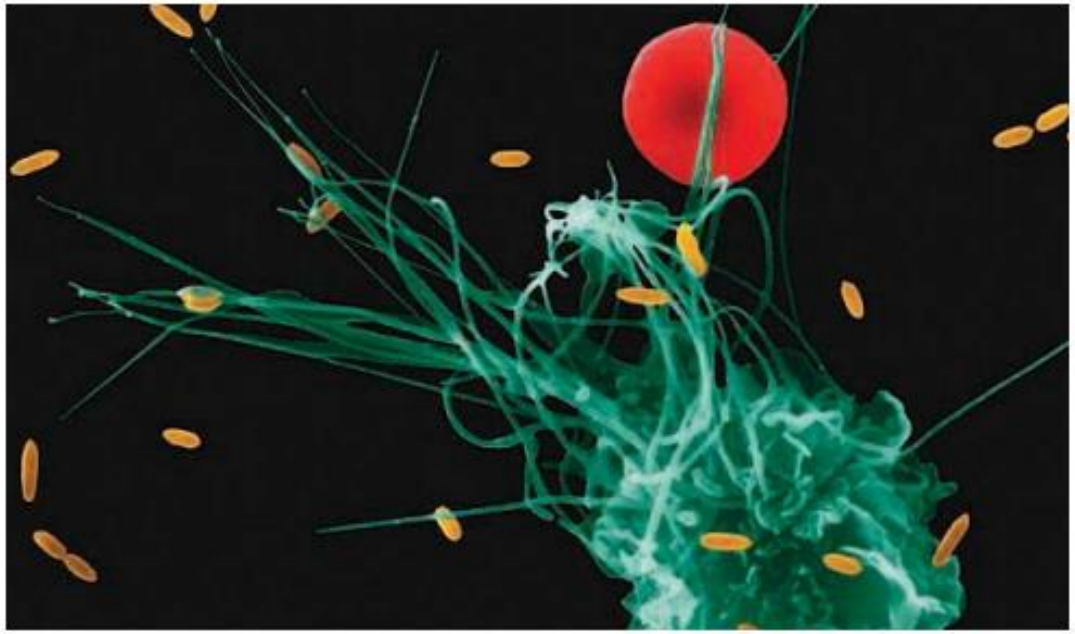
5) Fibrin is an insoluble material that forms a mesh of strands around the injured area. This mesh traps escaping blood cells and forms the clot.

COMPONENTS OF BLOOD

- WHITE BLOOD CELL COLOURLESS BLOOD CELL THAT PROTECTS THE BODY FROM INFECTION BY WAY OF THE IMMUNE RESPONSE; ALSO KNOWN AS A LEUCOCYTE

- LEUCOCYTES MAKE UP ABOUT 1 PERCENT OF YOUR TOTAL BLOOD VOLUME BUT MAY INCREASE TO MORE THAN DOUBLE NORMAL LEVELS WHEN YOUR BODY IS FIGHTING AN INFECTION. ALL WHITE BLOOD CELLS HAVE NUCLEI AND APPEAR TO BE COLOURLESS.

Figure 7.17 A leucocyte, or white blood cell, attacking *Escherichia coli (E. coli)* bacteria. A single red blood cell is also visible.

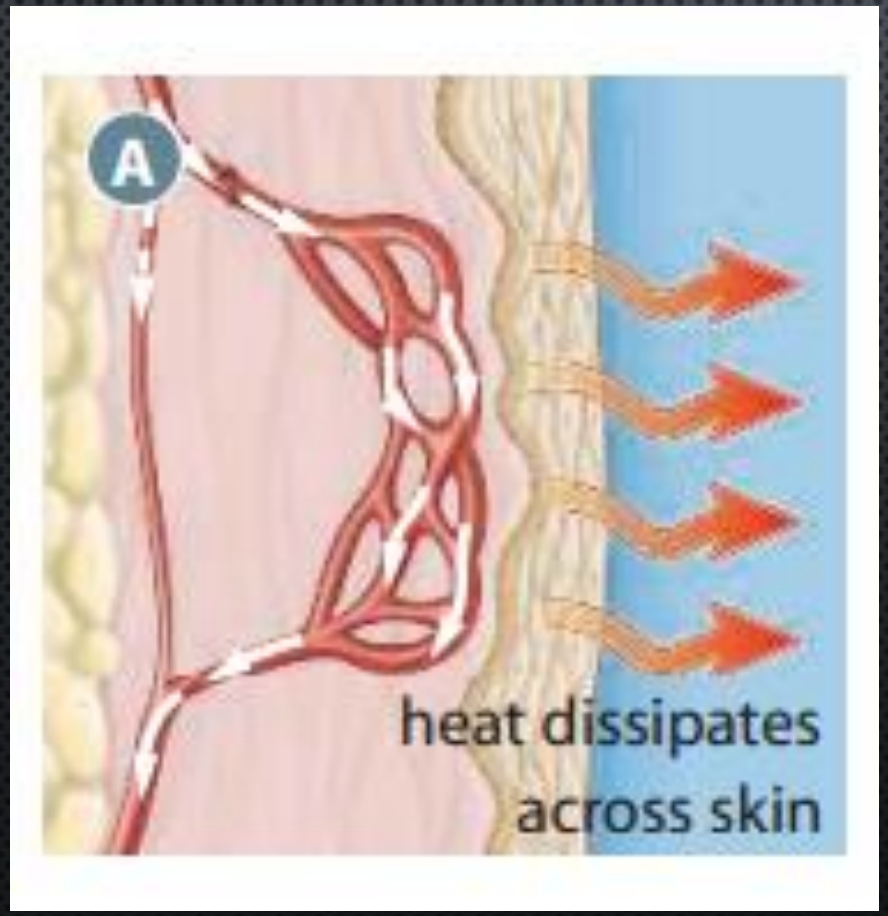


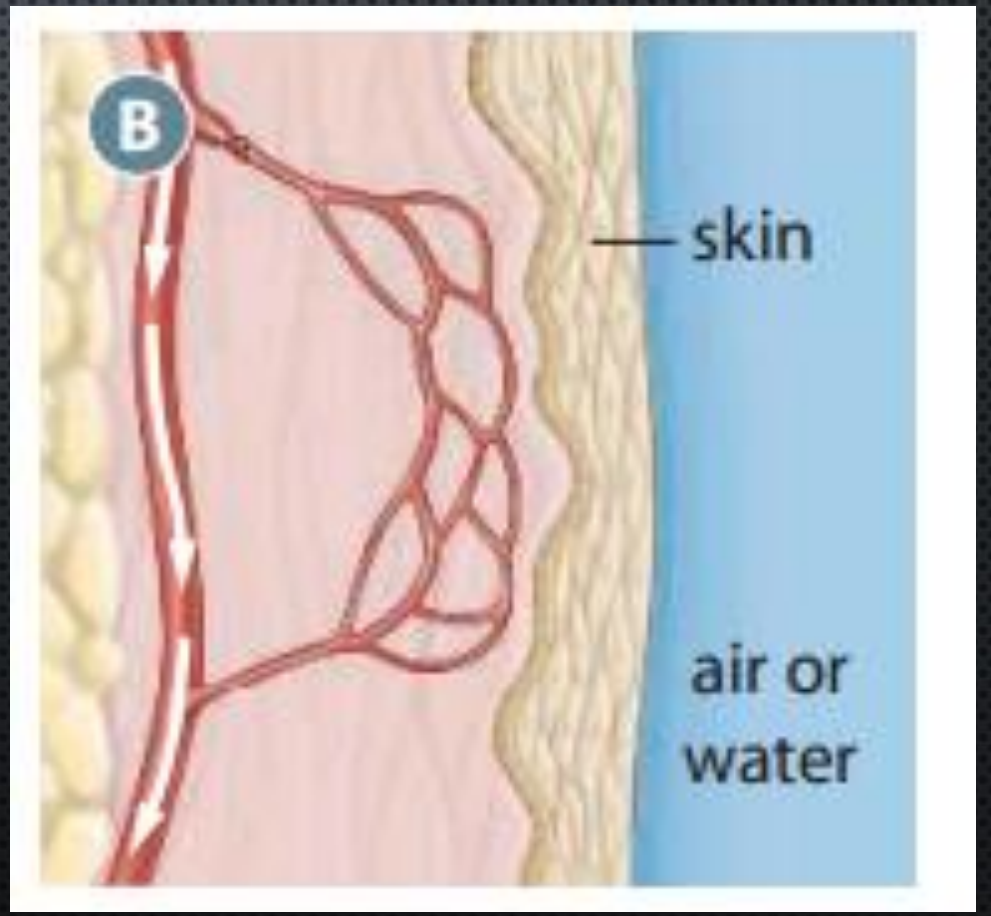
BLOOD AND HOMEOSTASIS

- ANOTHER IMPORTANT FUNCTION OF BLOOD IS TO MAINTAIN HOMEOSTASIS WITHIN THE BODY, ESPECIALLY IN RELATION TO TEMPERATURE REGULATION.
- TEMPERATURE REGULATION INVOLVES BALANCING HEAT PRODUCTION WITH HEAT LOSS.
- SHIVERING, INCREASE THE PRODUCTION OF HEAT BY CELLULAR METABOLISM. THE HEAT THAT IS PRODUCED IS SPREAD THROUGH THE BODY BY THE BLOOD.
- VASOCONSTRICTION DECREASE IN THE DIAMETER OF BLOOD VESSELS; VASOCONSTRICTION NEAR THE SKIN CONSERVES BODY HEAT
- VASODILATION EXPANSION IN THE DIAMETER OF BLOOD VESSELS; VASODILATION NEAR THE SKIN BRINGS MORE BLOOD TO THE SURFACE TO HELP REDUCE BODY TEMPERATURE

BLOOD AND HOMEOSTASIS

- FIGURE 7.19 VASODILATION (A) AND VASOCONSTRICTION (B)





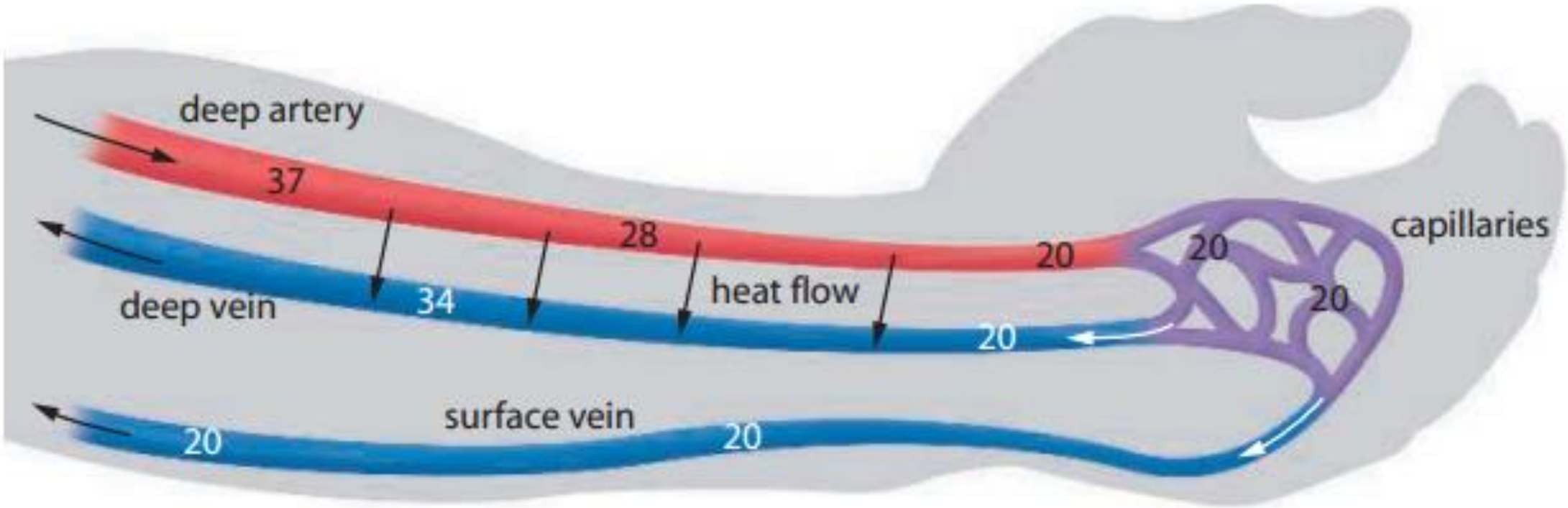


Figure 7.20 The counter-current heat exchange mechanism between the blood vessels in the human arm: The deep vein and artery are adjacent to one another, so heat is exchanged from one to the other. As a result, arterial blood is cooled as it nears the hand, and venous blood is warmed as it leaves the hand and returns to the body core. When heat conservation is important, more blood returns to the heart through the deep vein. In higher-temperature conditions, when heat conservation is not a concern, more blood returns through the surface vein. Numerals indicate the temperature of the blood in degrees Celsius.

CARDIOVASCULAR FITNESS

Table 7.1 Relationship among Stroke Volume, Heart Rate, and Cardiac Output

Individual	Resting Heart Rate (beats/min)	Stroke Volume (mL/beat)	Cardiac Output (mL/min)
A	70	70	4900
B	98	50	4900
C	35	140	4900

- According to this table, individual C's heart is exceptionally fit, having a very high stroke volume.
- C can maintain the same level of cardiac output (and oxygen delivery) at a much lower heart rate than the less fit heart of B or the average heart of A.
- This means that C's heart is working more efficiently than A's and B's.
- A low resting heart rate is considered an indicator of cardiovascular fitness because it means that stroke volume is high.

CARDIOVASCULAR FITNESS

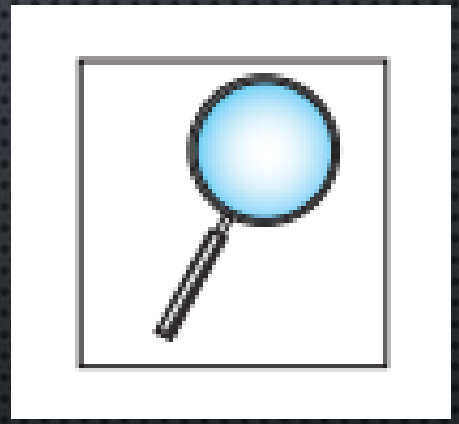
Table 7.1 Relationship among Stroke Volume, Heart Rate, and Cardiac Output

Individual	Resting Heart Rate (beats/min)	Stroke Volume (mL/beat)	Cardiac Output (mL/min)
A	70	70	4900
B	98	50	4900
C	35	140	4900

- MAXIMUM HEART RATE IS THE HIGHEST HEART RATE ATTAINED DURING AN ALL-OUT PHYSICAL EFFORT. THIS RATE DIMINISHES WITH AGE.
- MAXIMUM HEART RATE DOES NOT APPEAR TO BE RELATED TO CARDIOVASCULAR FITNESS, HOWEVER. THE MORE IMPORTANT CARDIOVASCULAR FITNESS INDICATOR IS THE LENGTH OF TIME IT TAKES FOR THE HEART TO RETURN TO ITS RESTING HEART RATE FOLLOWING PHYSICAL ACTIVITY.
- RECOVERY TIME DIMINISHES AS THE HEART BECOMES MORE FIT.

INVESTIGATION 7.B

- FACTORS AFFECTING HEART RATE AND BLOOD PRESSURE



- Activity 7.1 Cardiovascular Health, Technology and Society