Functional design of the CVS

Dr. Waleed R. Ezzat

Lecture Objectives:

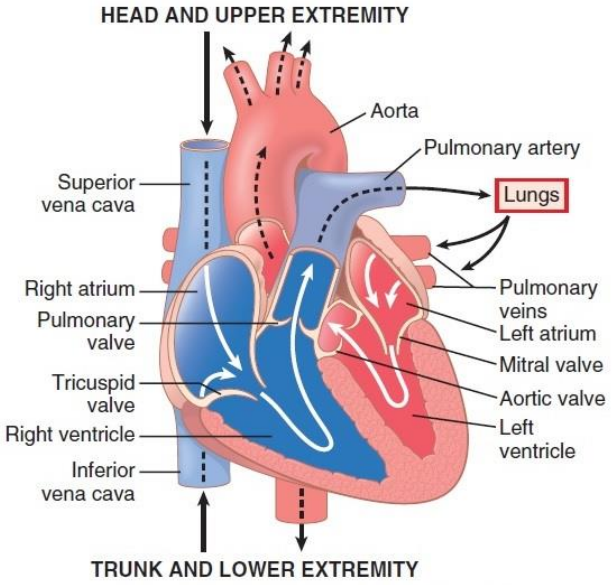
1. Describe the basic function of the CVS.
2. Explain how structural differences of various parts of CVS subserve their functions.
3. Describe the systemic and pulmonary circulations.
4. Describe blood velocity & blood flow through various parts of CVS in relation to their cross sectional area.

MAIN FUNCTIONS OF THE CIRCULATORY SYSTEM

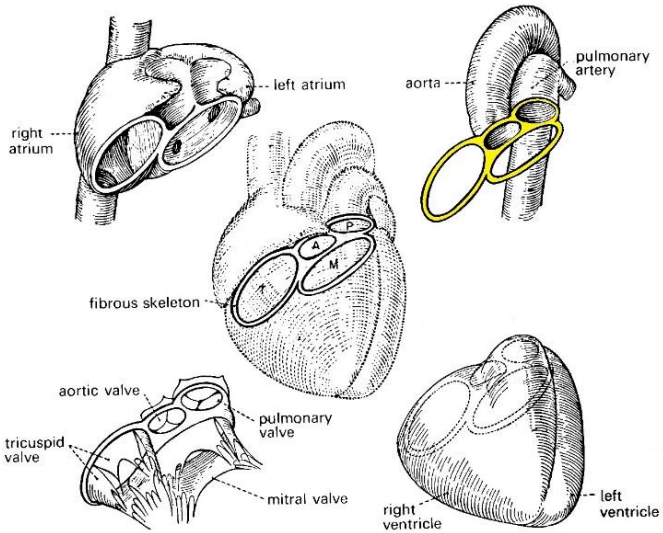
- Transport and distribute essential substances to the tissues
- Remove metabolic byproducts
- Adjustment of oxygen and nutrient supply in different physiologic states
- Regulation of body temperature (thermoregulation) and maintenance of fluid balance
- Humoral communication

Functional anatomy of the heart

- The heart looks like two cups facing each other mouth to mouth
- Atrial and ventricular myocardial fibers are attached to the **fibrous skeleton** of the heart
- The fibrous skeleton is made up from the union of **four** fibrous rings to which the four cardiac valves are attached
- There is no muscular communication between the atria and the ventricles
- The heart acts as two pumps arranged in series within a closed circuit



Structure of the heart and course of blood flow through the heart chambers and heart valves.



The Myocardium

- Myocardial fibers are arranged in a latticework, with the fibers dividing, recombining, and then spreading again.
- Cardiac muscle is *red and striated* as in skeletal muscle, however, cardiac muscle behaves like smooth muscle, i.e. it is *nerve regulated* and not nerve operated.
- Cardiac muscle is a **syncytium**. Individual myocardial cells are connected in series and in parallel with one another by the *intercalated discs*. These discs have gap junctions that allow rapid diffusion of ions and action potential.

Syncytial, interconnecting nature of cardiac muscle fibers.

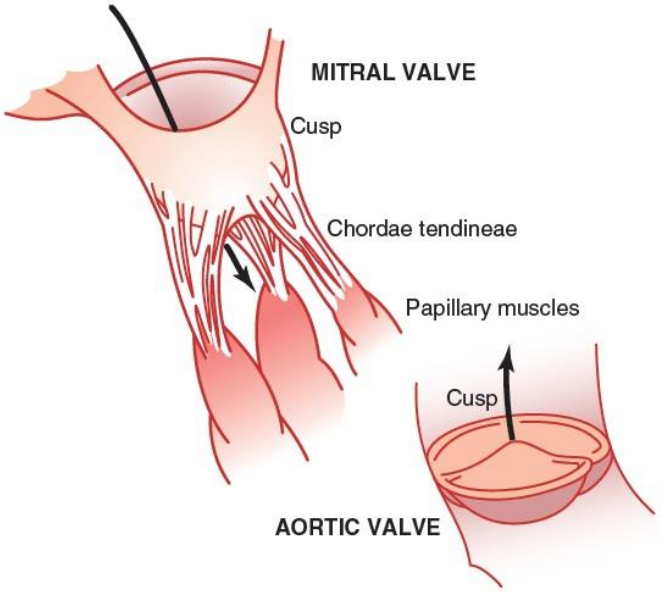
- The heart actually is composed of two syncytiums: the *atrial syncytium,* and the *ventricular syncytium.*
- This division of the muscle of the heart into two functional syncytiums allows the atria to contract a short time ahead of ventricular contraction, which is important for effectiveness of heart pumping.

Differences Between Myocardium and Skeletal Muscle

- The myocardium is red and striated, but it is nerve regulated (No motor units)
- Contraction can be graded
- Initial length is not fixed
- Requires extracellular Ca^{2+} for its contraction
- Cannot be tetanized → Acts as repeated simple muscle twitches
- Less powerful but cannot be fatigued practically
- Has high resting tension (tone) which is not nerve dependent (visco-elastic property)
- Highly stretchable (4-6X that of skeletal muscle)
- The mode of contraction is isotonic and auxotonic

Cardiac Valves

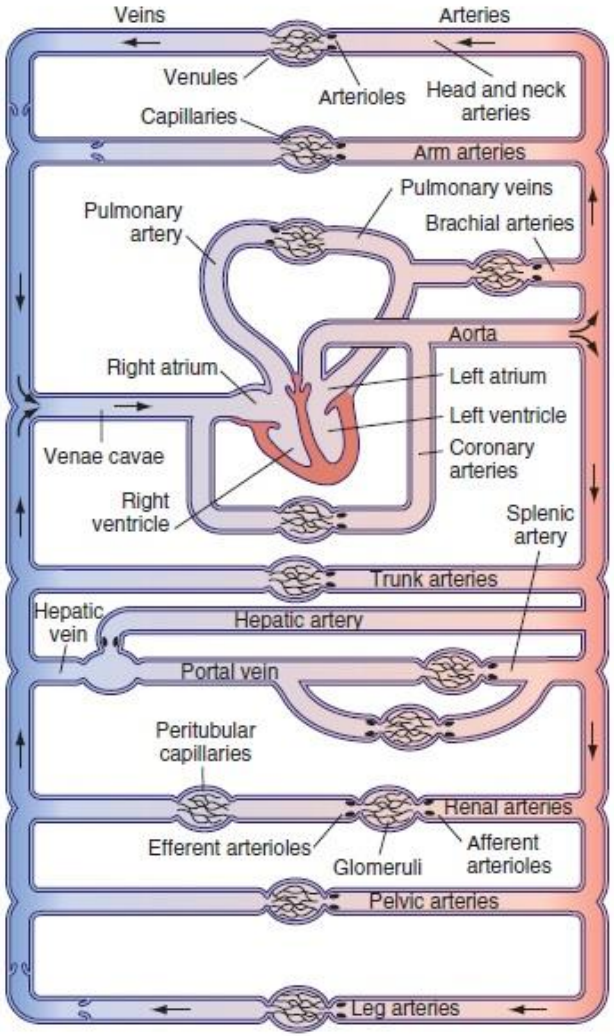
- The cardiac valve leaflets consist of thin flaps of flexible, tough, endothelium-covered fibrous tissue that are firmly attached at the base to the fibrous skeleton rings.
- Movement of the valve leaflets is essentially passive, and the orientation of the cardiac valves is responsible for the unidirectional flow of blood through the heart.
- There are two types of valves in the heart: **atrioventricular (AV)** and **semilunar**.
- Atrioventricular valves are the **tricuspid valve** (located between the right atrium and the right ventricle), is made up of three cusps, whereas the **mitral valve** (lies between the left atrium and the left ventricle), has two cusps.
- AV valves (also called the inlet valves) are funnel in shape. Attached to the free edges of these valves are fine, strong ligaments (chordae tendineae) that arise from the powerful papillary muscles of the respective ventricles.

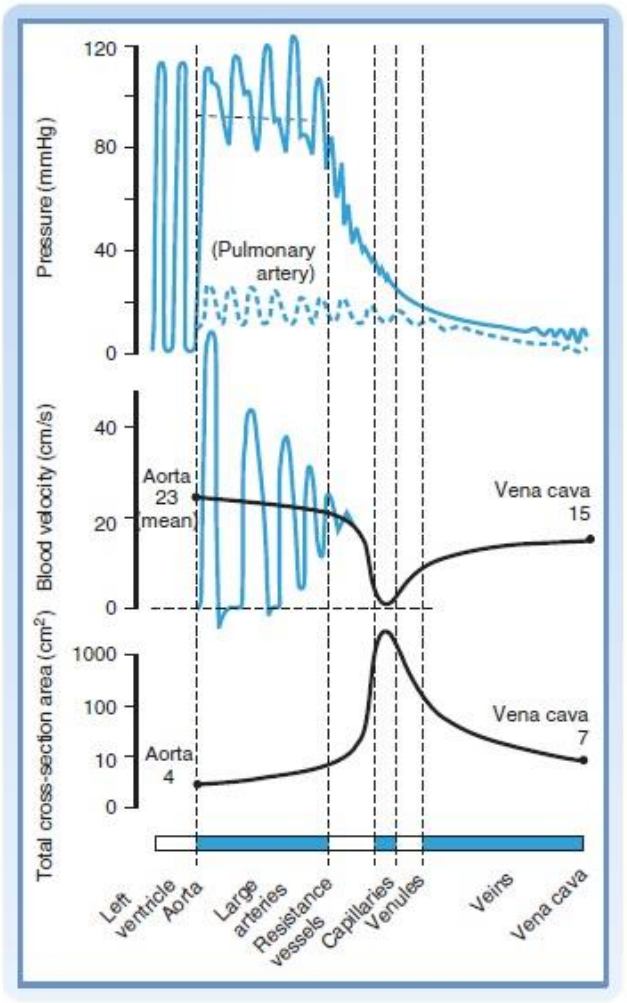


Mitral and aortic valves (the left ventricular valves).

Cardiac Valves (cont.)

- The chordae tendineae prevent the valves from becoming everted during ventricular systole.
- The semilunar valves (also called the outlet valves) are the **pulmonic** and **aortic valves** are located between the right ventricle and the pulmonary artery and between the left ventricle and the aorta, respectively.
- Four sounds are usually generated by the heart, but **only two** are ordinarily audible through a stethoscope.
- The first heart sound is initiated at the onset of ventricular systole and reflects closure of the AV valves.
- The second heart sound occurs with the abrupt closure of the semilunar valves.
- Valvular lesions (such as stenosis or incompetence) are usually associated with heart **murmurs**.





Right Fig. Schematic Diagram of the Parallel and Series Arrangement of the Vessels That Constitute the Circulatory System.

Left Fig. Phasic Pressure, Velocity of Flow, and Cross-Sectional Area of the Systemic Circulation. The important features are the major pressure drop across the small arteries and arterioles, the inverse relationship between blood flow velocity and cross-sectional area, and the maximal cross-sectional area and minimal flow rate in the capillaries.

Test Question:

Which one of the following statements concerning the mitral valve is correct?

A. It requires contraction of the papillary muscle in order to initiate closing

B. A murmur is produced when it fails to close properly

C. It closes at the end of ventricular contraction

D. Its closure normally generates the second heart sound

E. It prevents backflow of blood into the ventricle during ventricular relaxation (diastole)