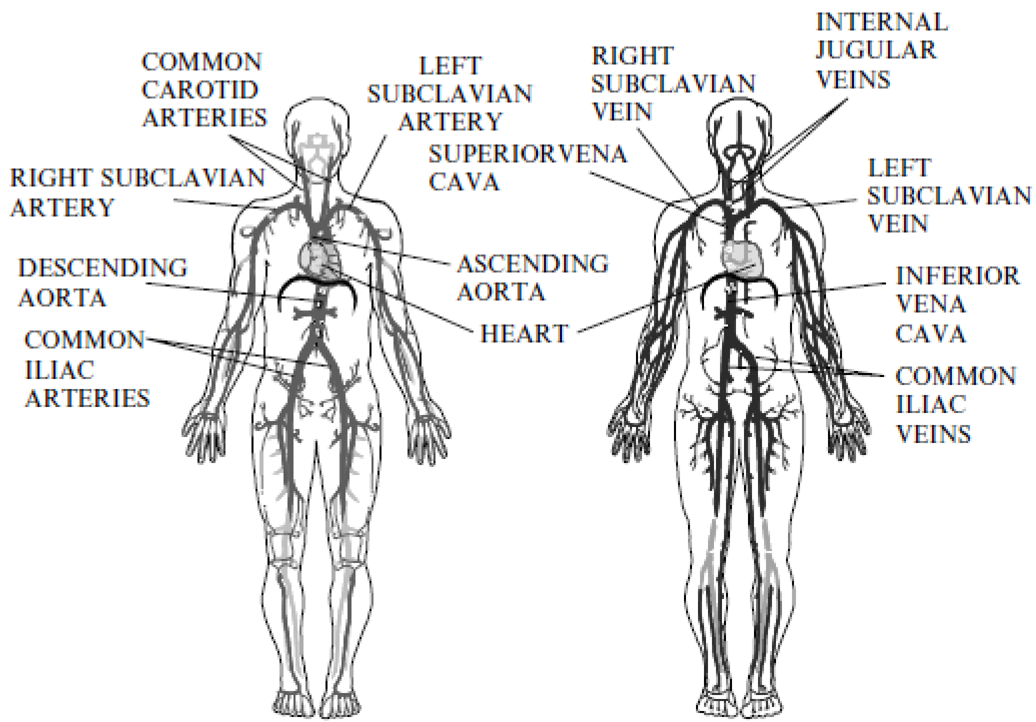
Circulatory System



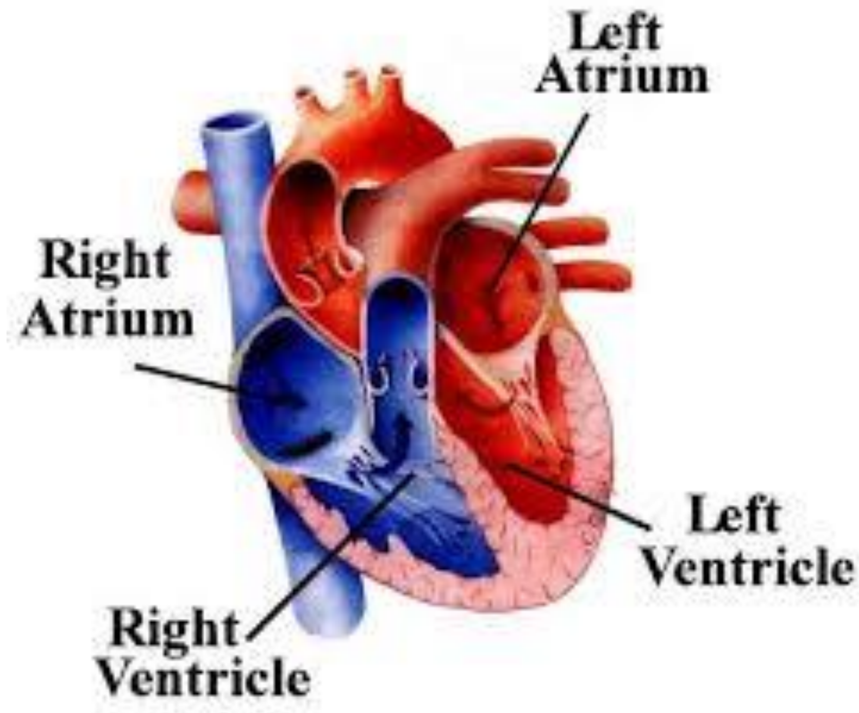
delivers nutrients and hormones throughout the body 1

removes waste products from tissues 2

provides a mechanism for regulating temperature and removing the heat generated by the metabolic activities of the body's internal organs 3

Every living cell in the body is no more than 10–100 μm from a capillary (small blood vessels with walls only one cell thick that are 8 μm in diameter, approximately the same size as a red blood cell).

This close proximity allows oxygen, carbon dioxide, and most other small solutes to diffuse from the cells into the capillary or from the capillary into the cells with the direction of diffusion determined by **concentration** and **partial pressure gradients.**



The heart

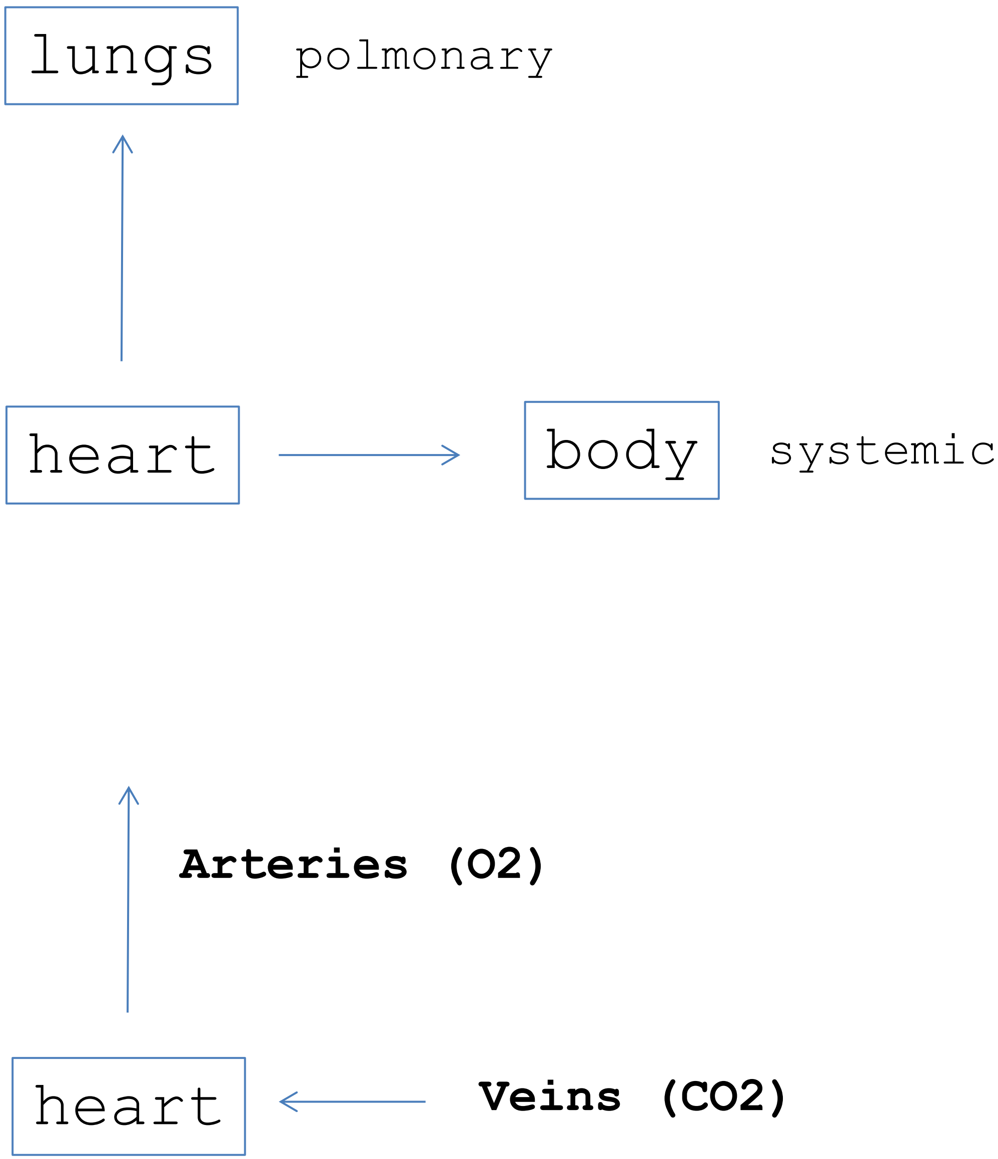
the pumping station that moves blood through the blood vessels

consists of two pumps—the right side and the left side

Each side has one chamber (the **atrium**) that **receives** blood and another chamber (the **ventricle**) that **pumps** the blood away from the heart

The **right** side moves **deoxygenated** blood to the lungs

The **left** side receives **oxygenated** blood the lungs and pumps it to the body

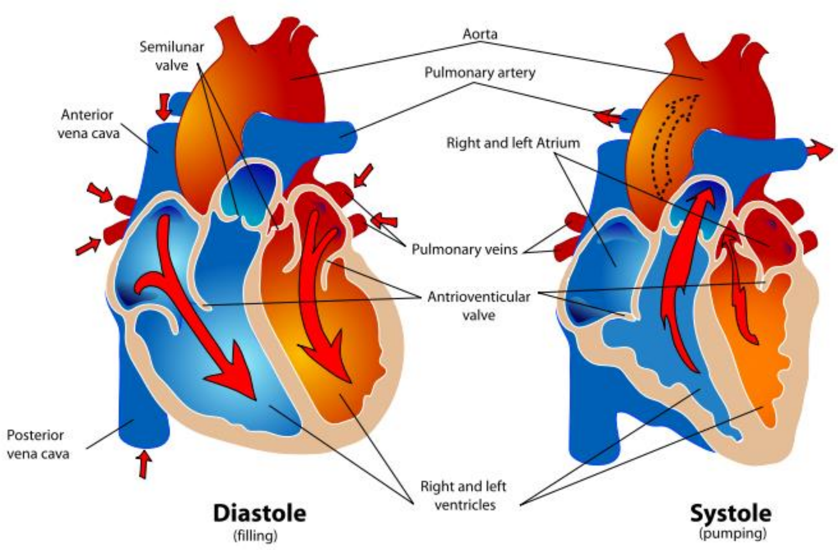


The average adult has about **5 L** of blood with 80-90% in the systemic circulation at any one time;

75% of the blood is in the systemic circulation in the veins, 20% in the arteries, and 5% in the capillaries.

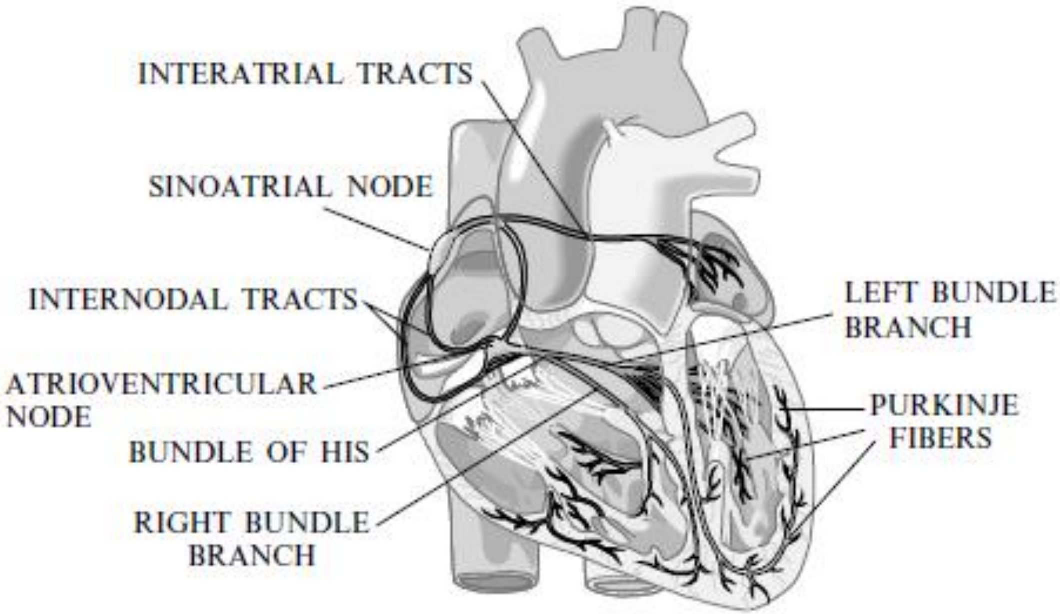
Cardiac output is the **product** of the **heart rate** and the volume of blood pumped from the heart with each beat (i.e., the **stroke volume**)

Each time the heart beats, about **80 ml** of blood leave the heart. Thus, it takes about **60** beats for the average red blood cell to make one complete cycle of the body



the cardiac cycle

the repeating pattern of *contraction* (systole) and *relaxation* (diastole)

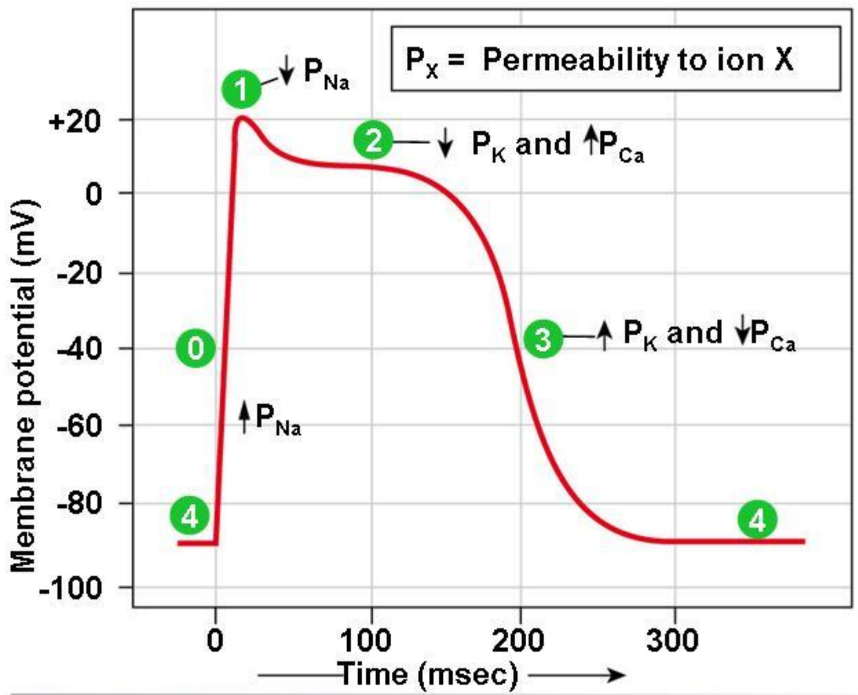


the cardiac cycle begins with a **self-generating electrical pulse** in the pacemaker cells of the sinoatrial node

This is the result of the movement of ions across their plasma membranes.

The permeability of the plasma membrane to Na+ changes dramatically and allows these ions to rush into the cell.

Depolarization: electrical potential across the plasma membrane from one in which the interior of the cell is **more negative** than the extracellular fluid (approximately 90 mV) to **more positive** than the extracellular fluid (approximately 20 mV)



Phase	Membrane channels
0	Na^+ channels open
1	Na^+ channels close
2	Ca^{2+} channels open; fast K^+ channels close
3	Ca^{2+} channels close; slow K^+ channels open
4	Resting potential

The entire electrical event in which the polarity of the potential across the plasma membrane rapidly reverses and then becomes reestablished is called an **action potential**

The cells in the sinoatrial node depolarize on the average of every **0.83** s in a typical adult at rest

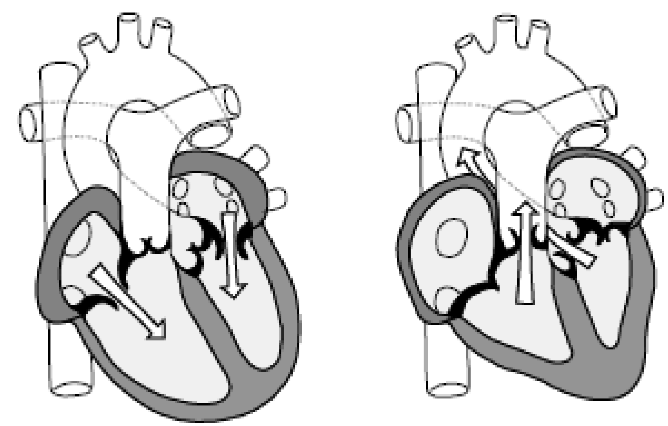
This gives a resting heart rate of **72 beats per minute** with about 5/8 of each beat spent in diastole and 3/8 in systole.

1. Action potentials spread from one cell to the next

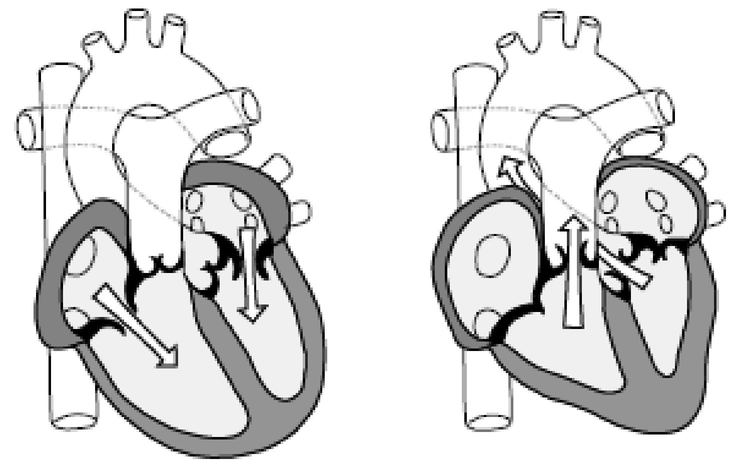
2. Activation wavefronts move across the atria at a rate of about 1 m/s

3. When cardiac cells depolarize, they also contract

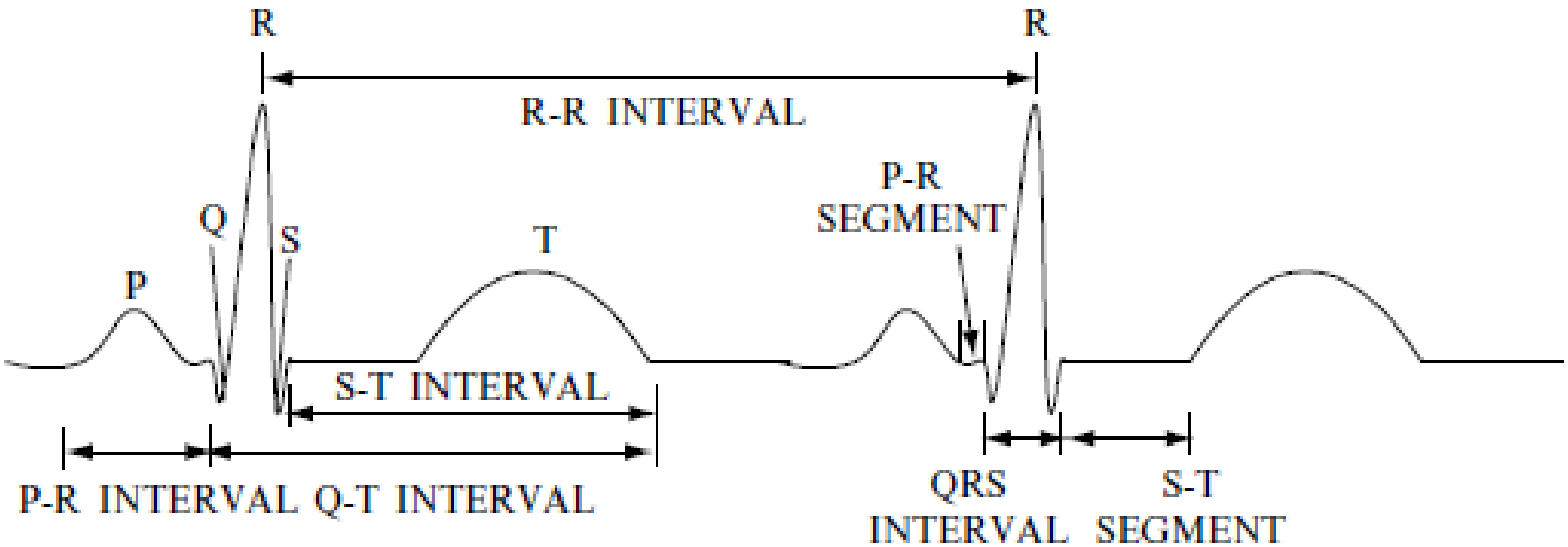
4. The contraction process in the atria moves blood to the **ventricles**



5. The activation wavefront then moves to the *atrioventricular* (AV) node where it slows to a rate of about 0.05 m/s to allow time for the ventricles to completely fill with the blood from the atria



6. After leaving the AV node, the activation wavefront moves to specialized conduction tissue, the **Purkinje system**, which spreads the wavefront very rapidly (at about **3 m/s**) to many cells in both ventricles. The activation wavefront spreads through **ventricular tissue at about 0.5 m/s**. This results in the simultaneous contraction of both ventricles (ventricular systole) so that blood is forced from the heart into the pulmonary artery from the right ventricle and into the aorta from the left ventricle.



ECG

I. The **P** wave represents the depolarization of the atria

II. The **QRS** represents the depolarization of the ventricles

III. Ventricular repolarization shows up as the **T** wave

IV. Atrial repolarization is masked by ventricular depolarization

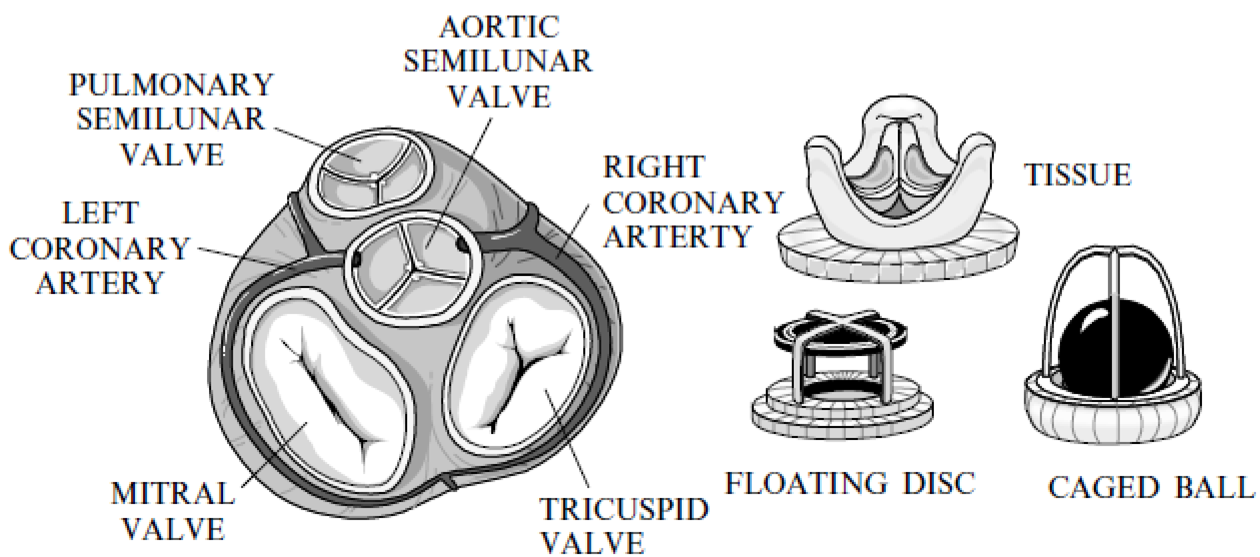
Changes in the amplitude and duration of the different parts of the ECG provide diagnostic information for physicians. Many biomedical engineers have worked on methods for recording and analyzing ECGs.

See example

During atrial and ventricular systole, special one-way valves keep the blood moving in the correct direction

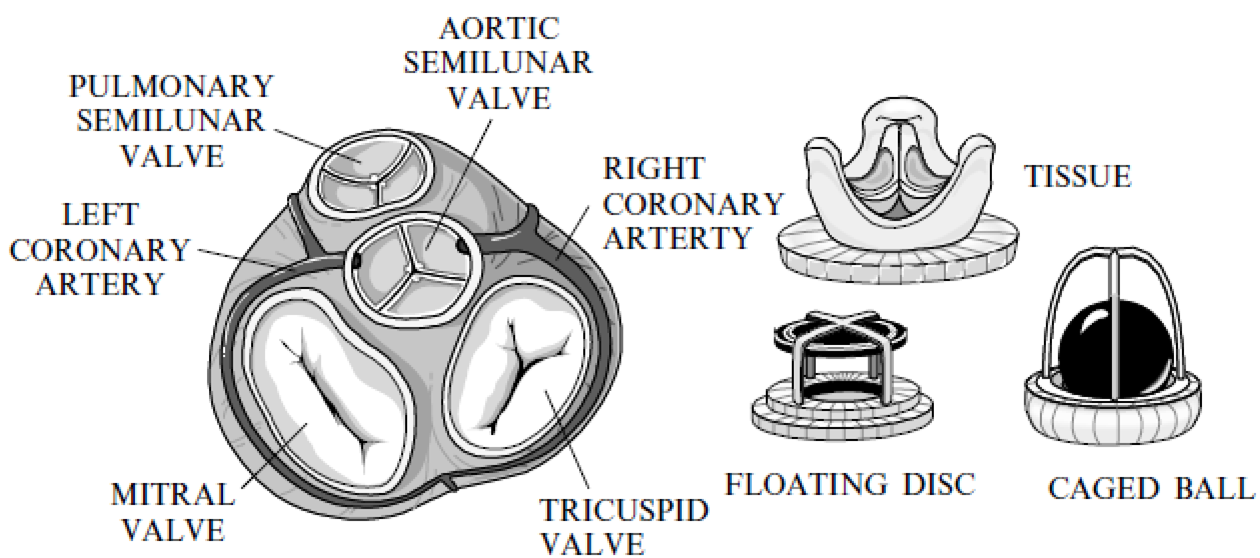
When the atria contract, the atrioventricular valves (tricuspid and mitral) open to allow blood to pass into the ventricles

During ventricular systole, the semilunar valves (aortic and pulmonary) open to allow blood to leave the heart while the atrioventricular valves close and prevent blood from flowing backwards from the ventricles to the atria



The aortic and pulmonary valves prevent blood from flowing back from the pulmonary artery and aorta into the right and left ventricles, respectively

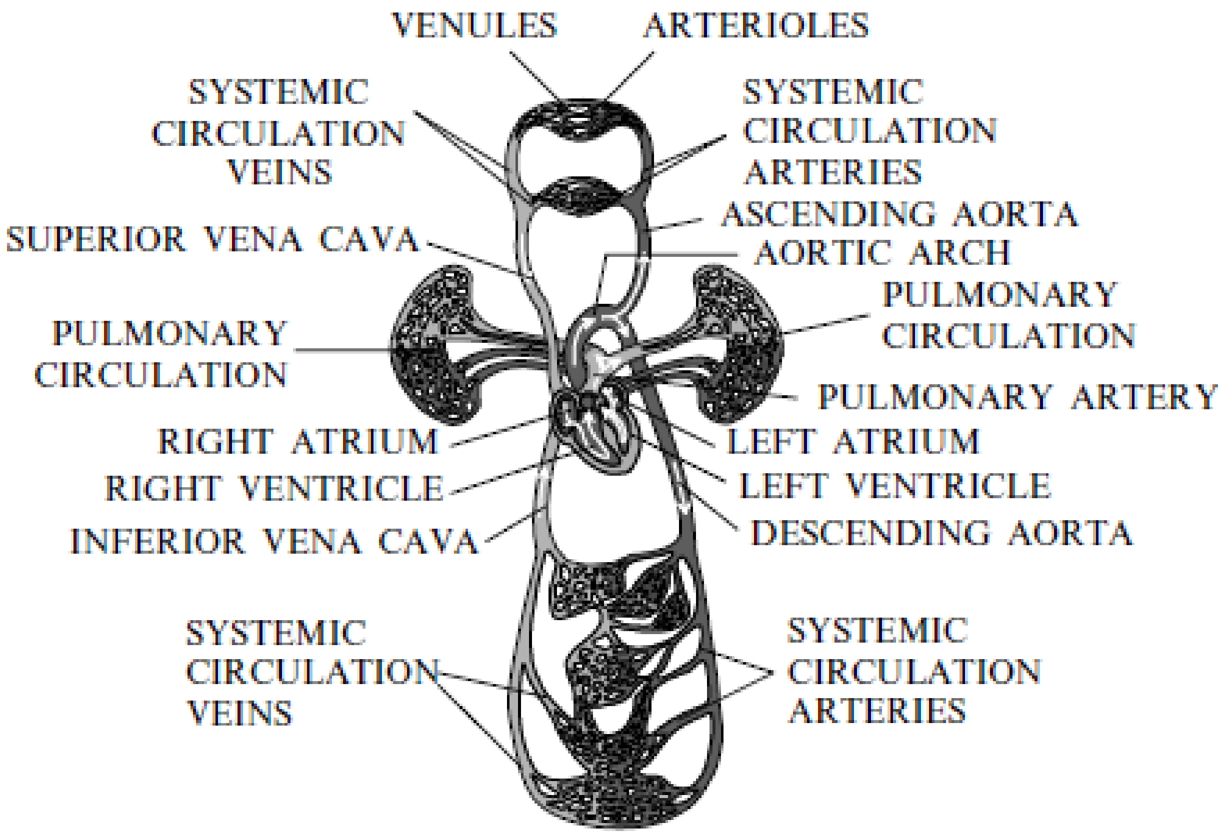
If a valve becomes calcified or diseased or is not properly formed during embryonic development, it can be replaced by an artificial valve), a device that has been developed by cooperative work between biomedical engineers and physicians.



Blood in the systemic circulation leaves the **heart** through the **aorta** with an average internal pressure of about 100mmHg and moves to **medium sized arteries and arterioles.** Arterioles lead to **capillaries** (average internal pressure of about 30mm Hg), which are followed by **venules. Venules** lead to **medium-sized veins,** then to **large veins,** and finally to the **venae cavae** (average internal pressure of about 10mm Hg) which return blood to the heart at the right atrium.

Blood in the pulmonary circulation leaves the **pulmonary artery** and moves to **arterioles** and then the **capillary beds within the lungs.** It returns to the heart through the left atrium. Blood flow is highest in the large arteries and veins (30-40 cm/s in the aorta; 5 cm/s in the venae cavae) and slowest in the capillary beds (1 mm/s) where the exchange of nutrients, metabolic wastes, gases, and hormones takes place.

Pressures in the pulmonary circulation are lower (25mm Hg/10mm Hg) than in the systemic circulation due to the decreased pumping power of the smaller right ventricle as compared to the left and to the lower resistance of blood vessels in the lungs.


VENULES
ARTERIOLES
SYSTEMIC CIRCULATION VEINS
SYSTEMIC CIRCULATION ARTERIES
ASCENDING AORTA
SUPERIOR VENA CAVA
AORTIC ARCH
PULMONARY CIRCULATION
PULMONARY CIRCULATION
PULMONARY ARTERY
RIGHT ATRIUM
LEFT ATRIUM
RIGHT VENTRICLE
LEFT VENTRICLE
INFERIOR VENA CAVA
DESCENDING AORTA
SYSTEMIC CIRCULATION VEINS
SYSTEMIC CIRCULATION ARTERIES