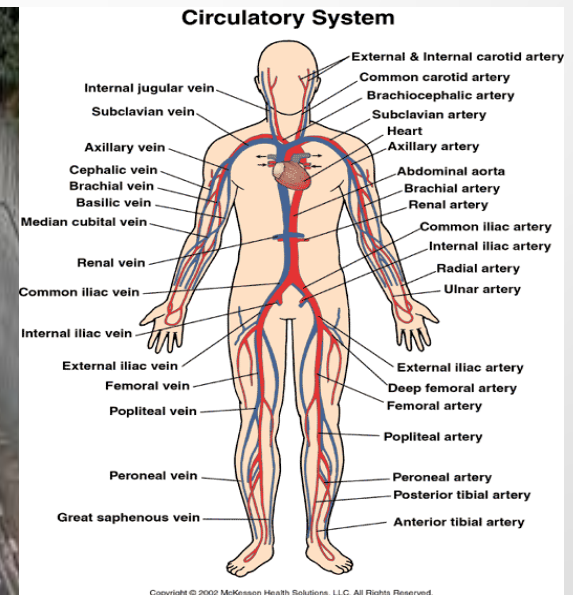


Intro to Exercise Physiology – Cardiovascular System



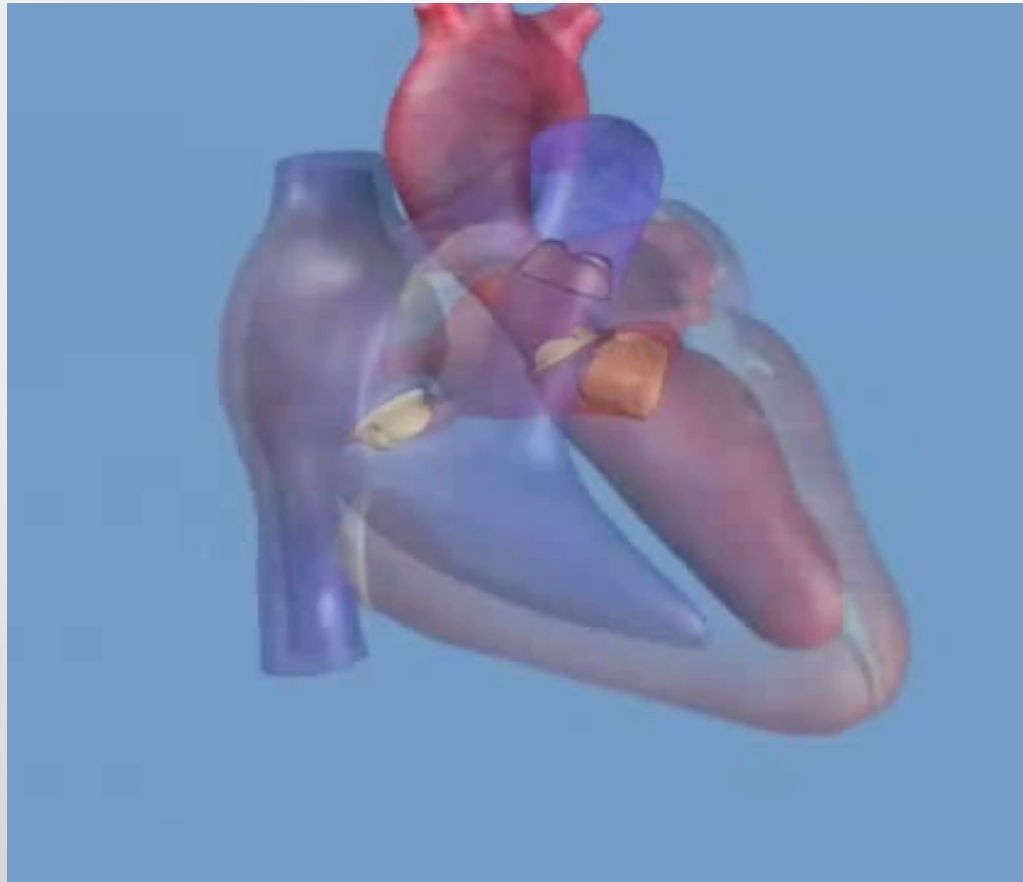
Functions of the Circulatory system

- Delivery e.g. oxygen / nutrients
- Removal e.g. carbon dioxide / lactic acid
- Transport e.g. hormones
- Maintenance e.g. core temperature/ hydration
- Prevention e.g. infection

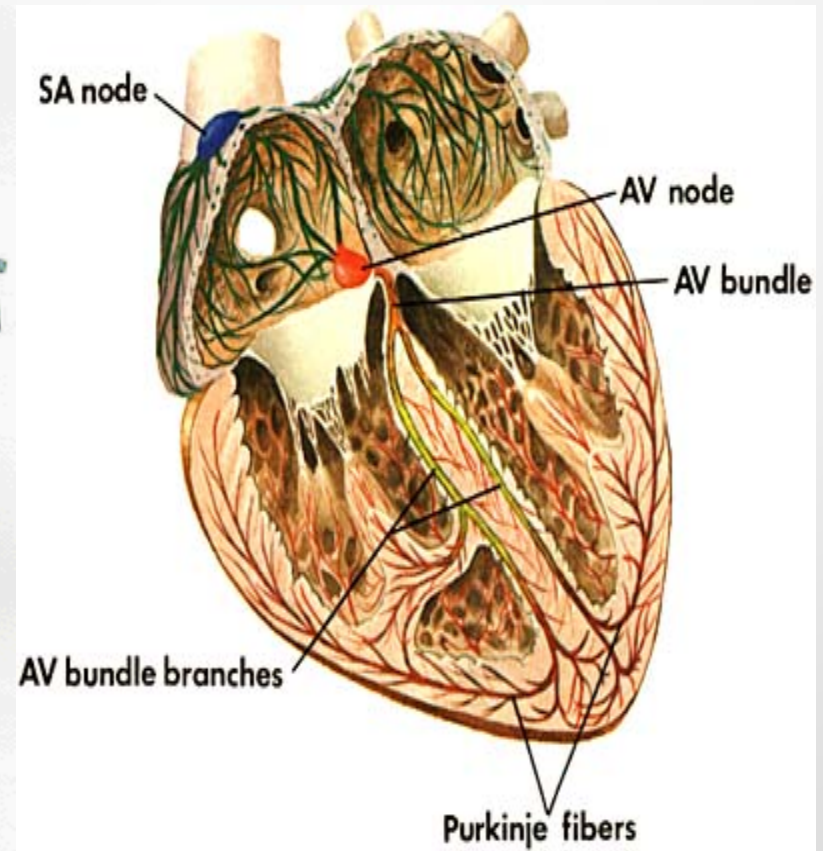
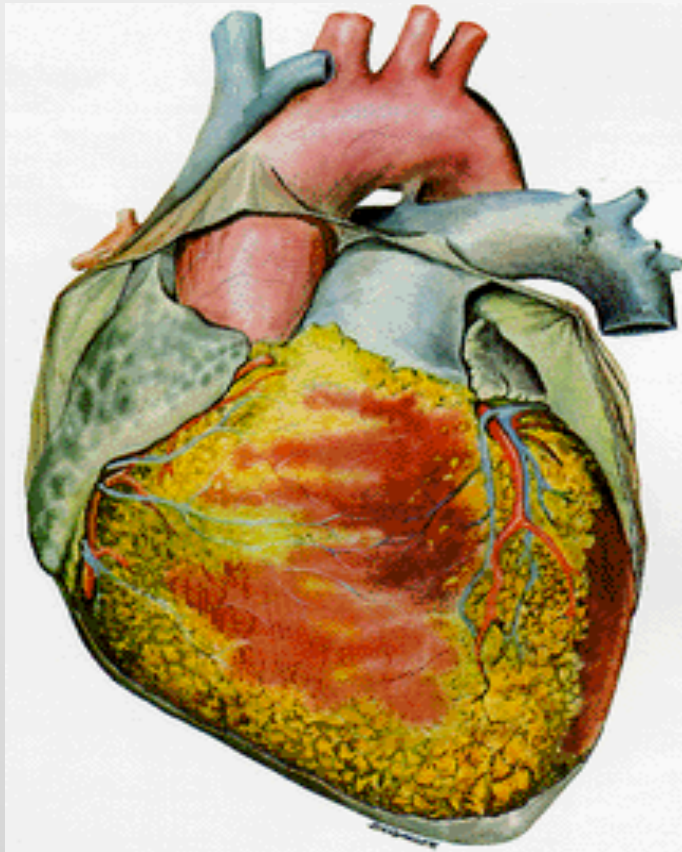
Structures of the cardiovascular system

- Blood
- Arteries
- Arterioles
- Capillaries
- Venules
- Veins
- Heart

Function of the Heart

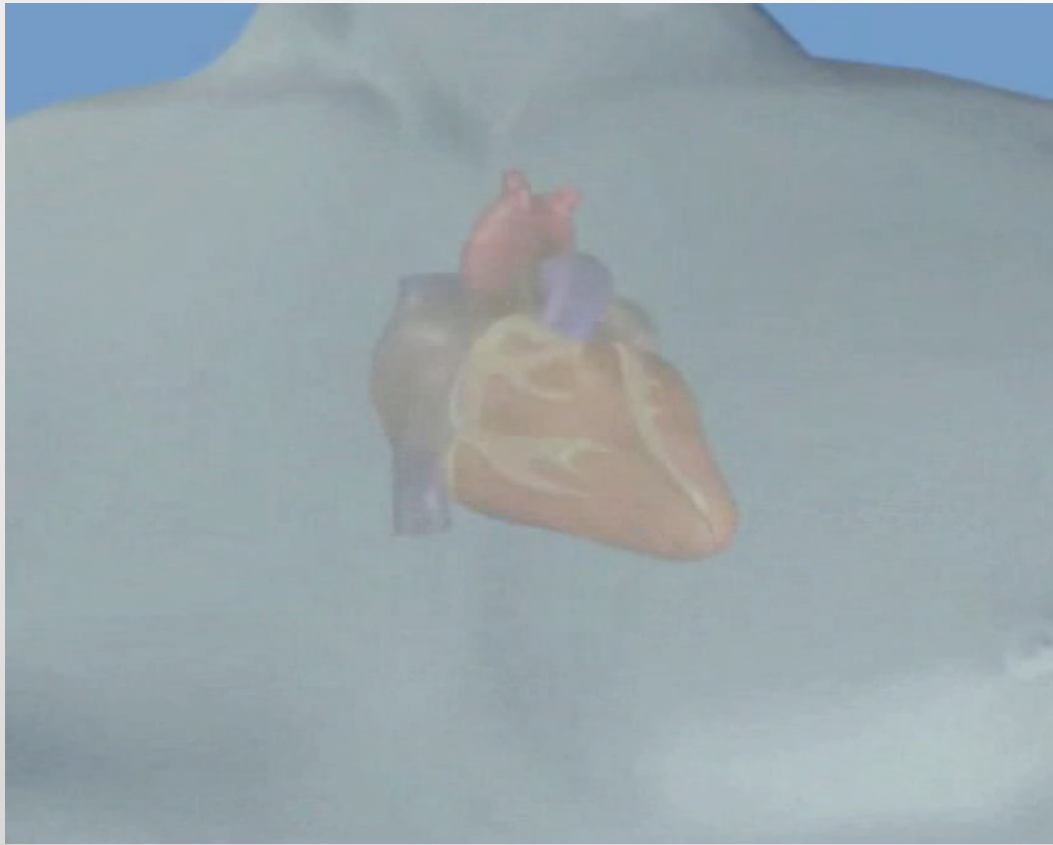


The Heart



- 
- Veins (Pulmonary and Vena Cava)
 - Arteries (Pulmonary and Aorta)
 - Valves (Semilunar, tricuspid and bicuspid)
 - Atria (left and right)
 - Ventricles (left and right)
 - Sino-atrial node (Top of right atrium)
 - Atrio-ventricular node (atrial septum and tricuspid valve)
 - Bundles of His (AV bundle) + left and right Purkinje Fibers (electrical transmission)
 - Septum (atrial and ventricular)

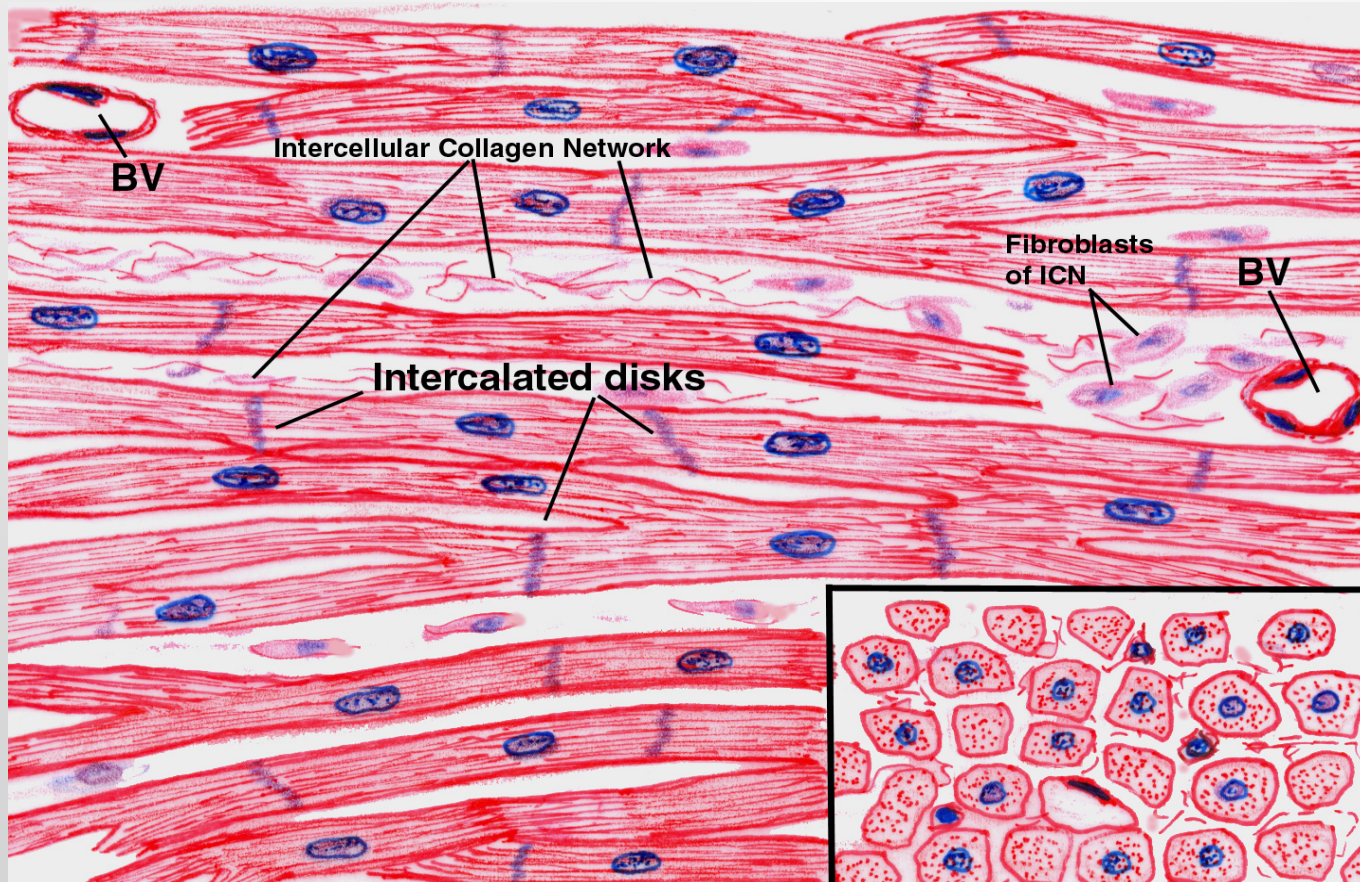
Heart Anatomy



Heart Muscle / Cardiac

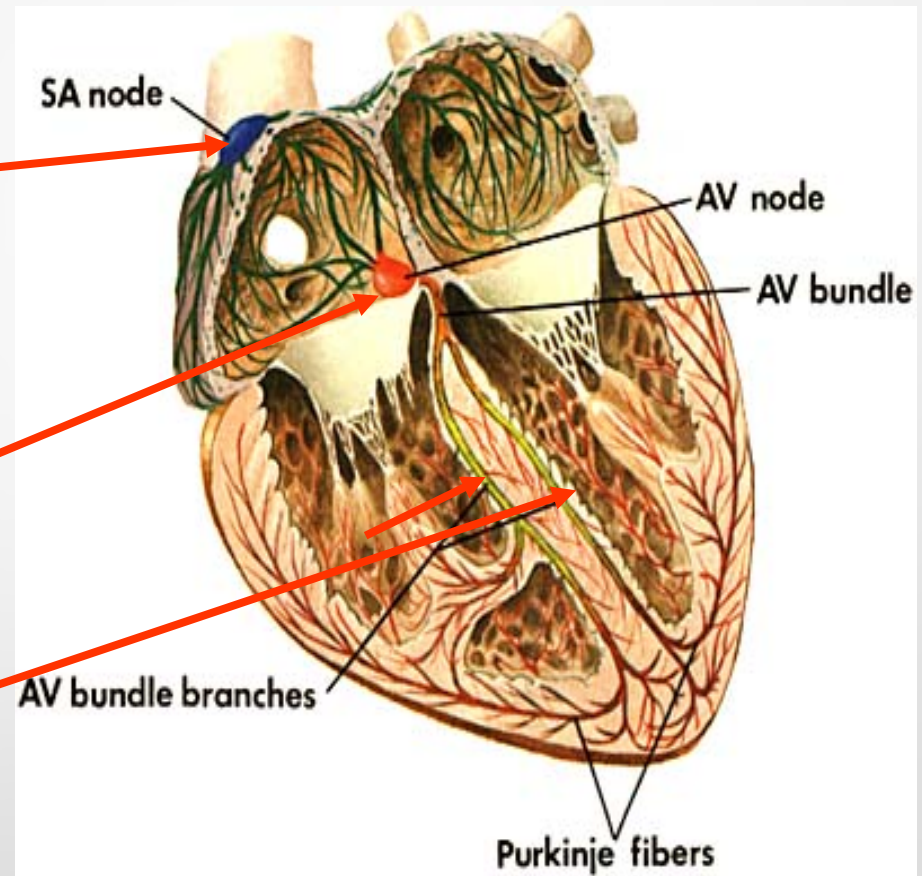
- Myocardium
- Varies in thickness (left ventricle thickest)
- Muscle fibres striated but joined by intercalated discs.
- One impulse initiates the whole heart to contract (obeys all or nothing law).
- Supplied with blood from coronary vessels

Cardiac Muscle

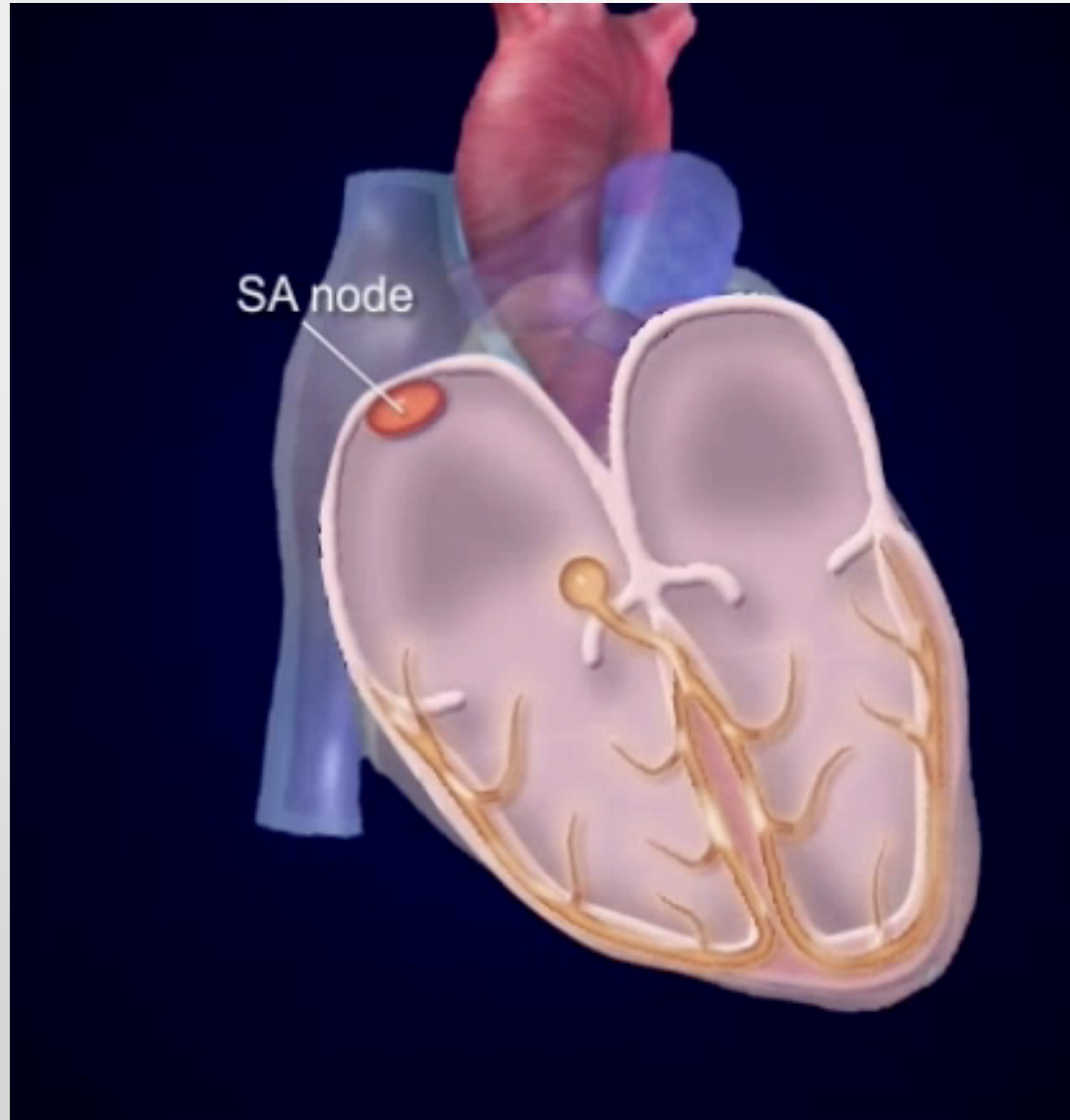


Heart Rate

- All the cells of the heart are able to generate an electrical impulse.
- However the Sino-atrial node is the primary pacemaker and overrides all other impulse initiators (80-100 bts/ min)
- Secondary pacemaker is the atrioventricular node (40-60 bts/min)
- The Bundles of His, the left and right branches of this bundle, and the Purkinje fibres are the tertiary pacemaker (30-40 bts/min)



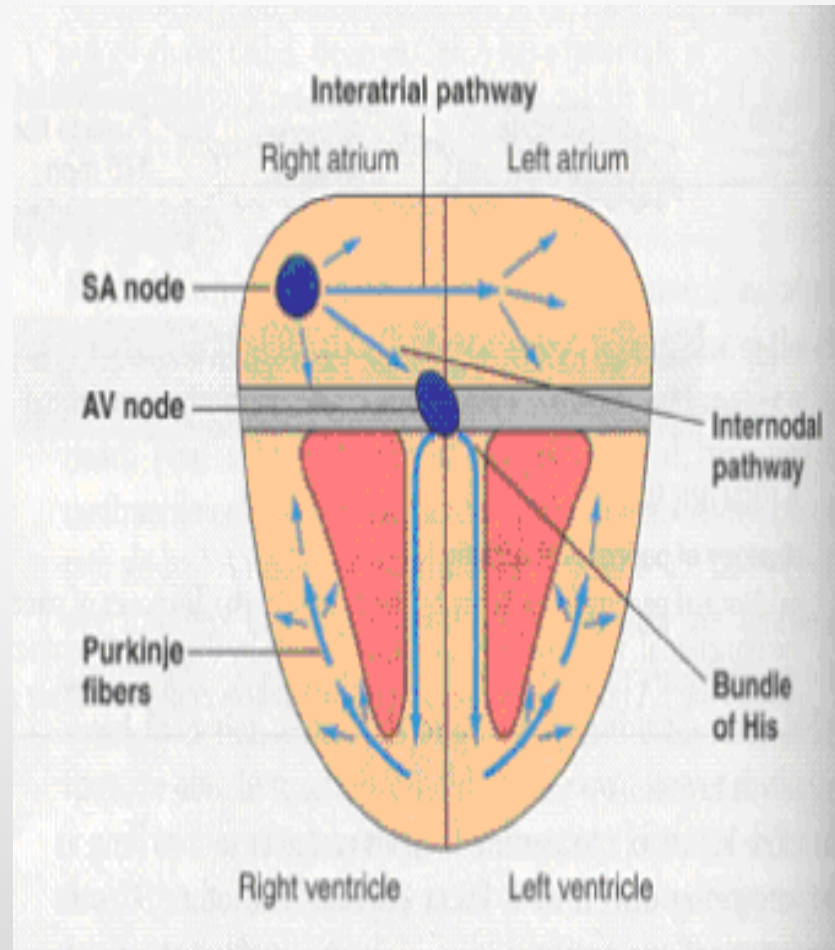
Conduction through the Heart

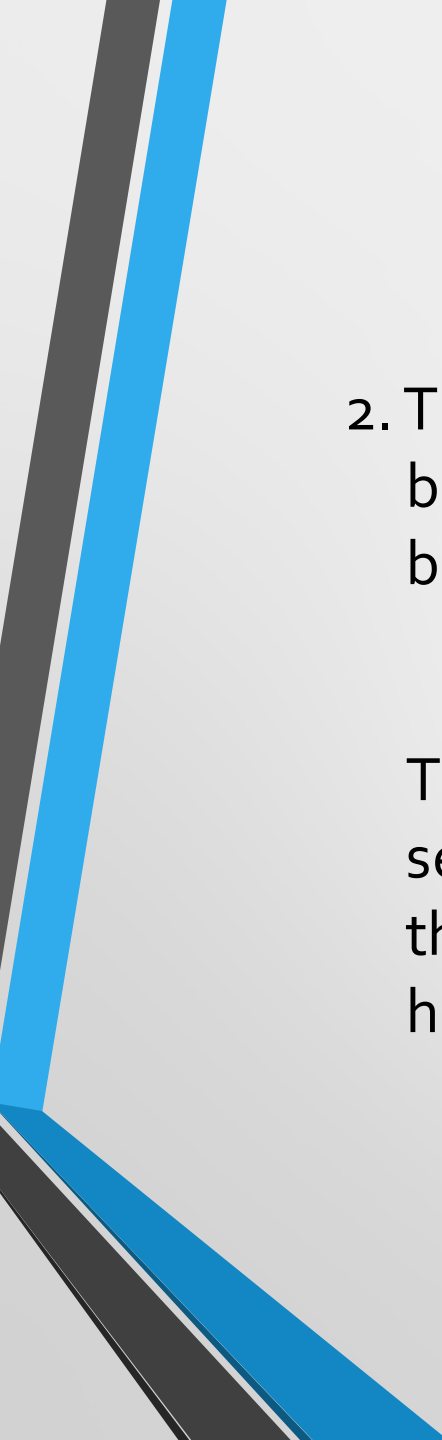


Cardiac Cycle

1. Impulse generated at sino-atrial node

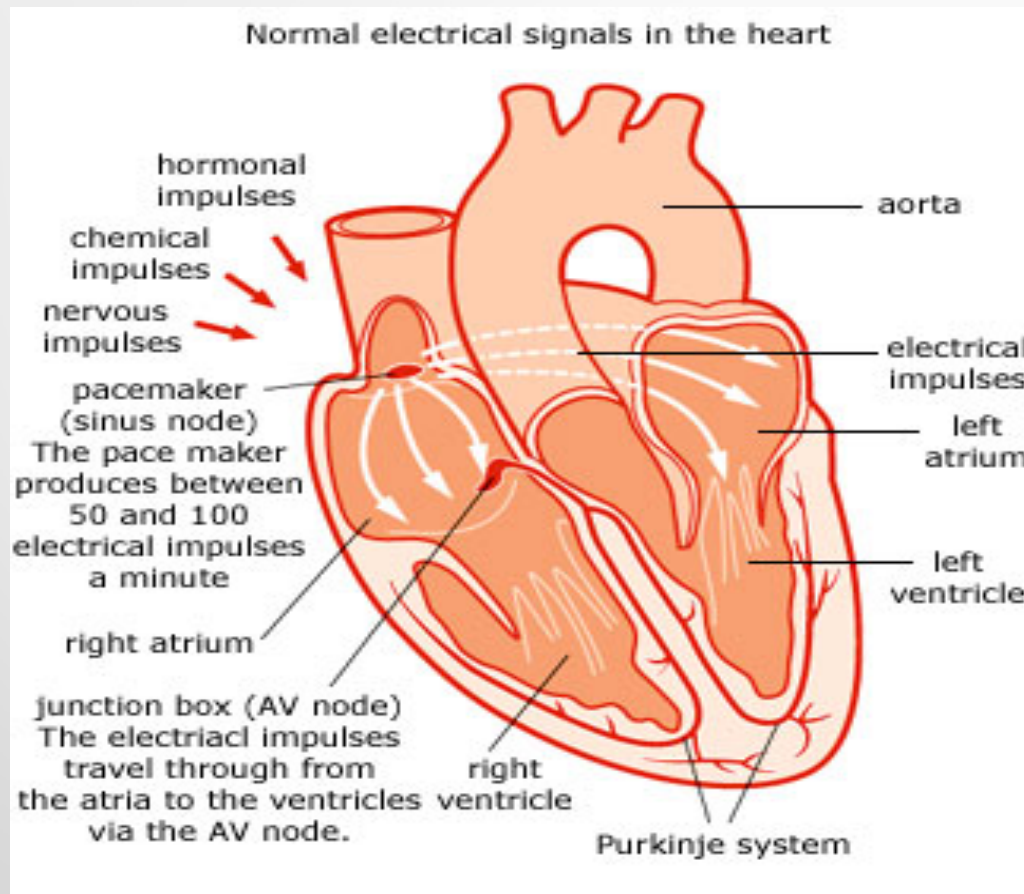
Impulse caused by the change in electrical polarity in the SA node by flow of sodium and potassium



- 
2. The impulse travels from AV node into the AV bundle (bundle of His), splits into left and right branches and into Purkinje fibres.

The bundles of His are contained in the ventricular septum which prohibits leakage of the impulse to the cardiac muscle before it reaches the apex of the heart

Bundles of His and Purkinje Fibres

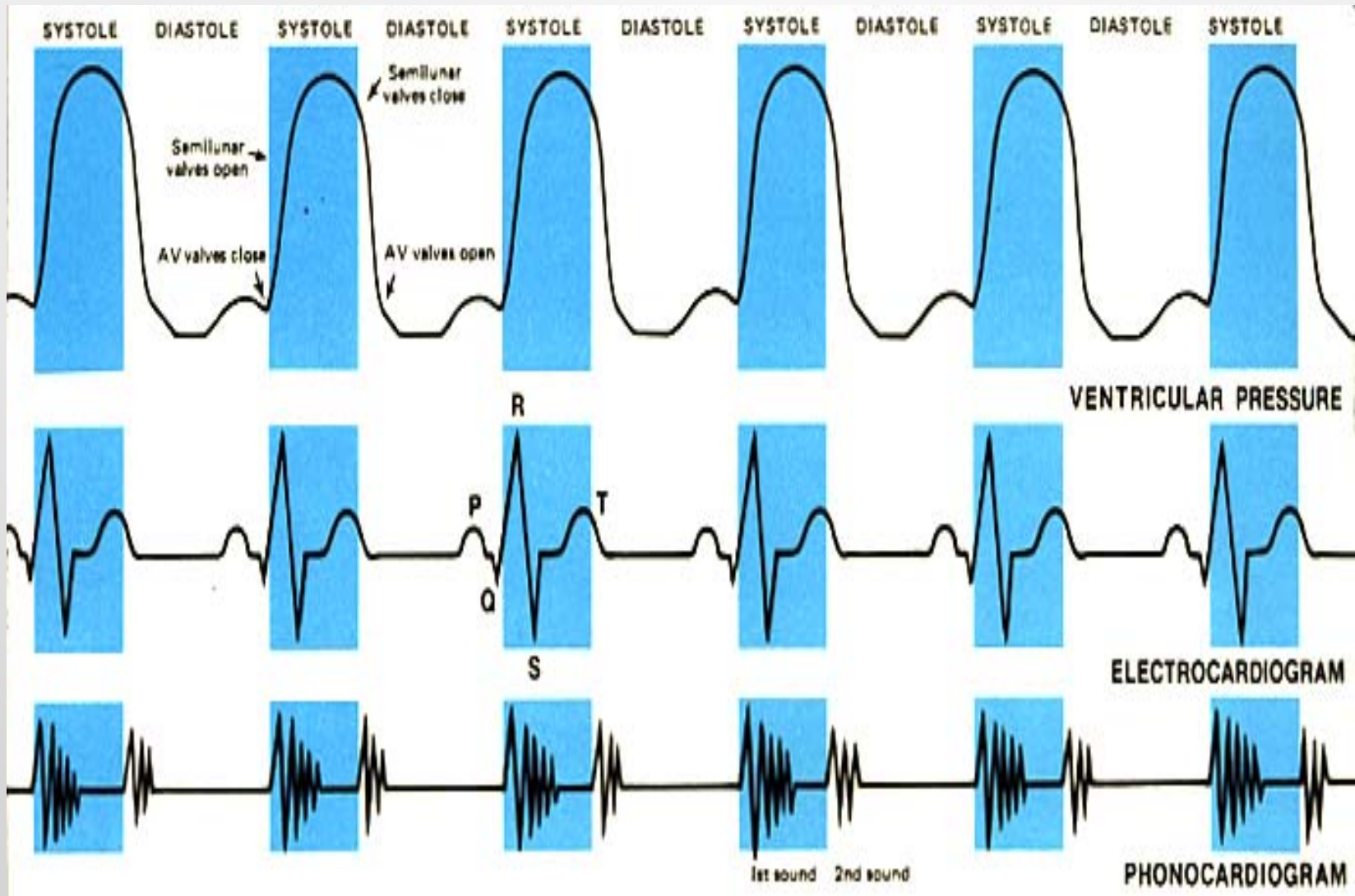


- 
3. The impulse spreads out through the Purkinje fibres from the apex of the heart.

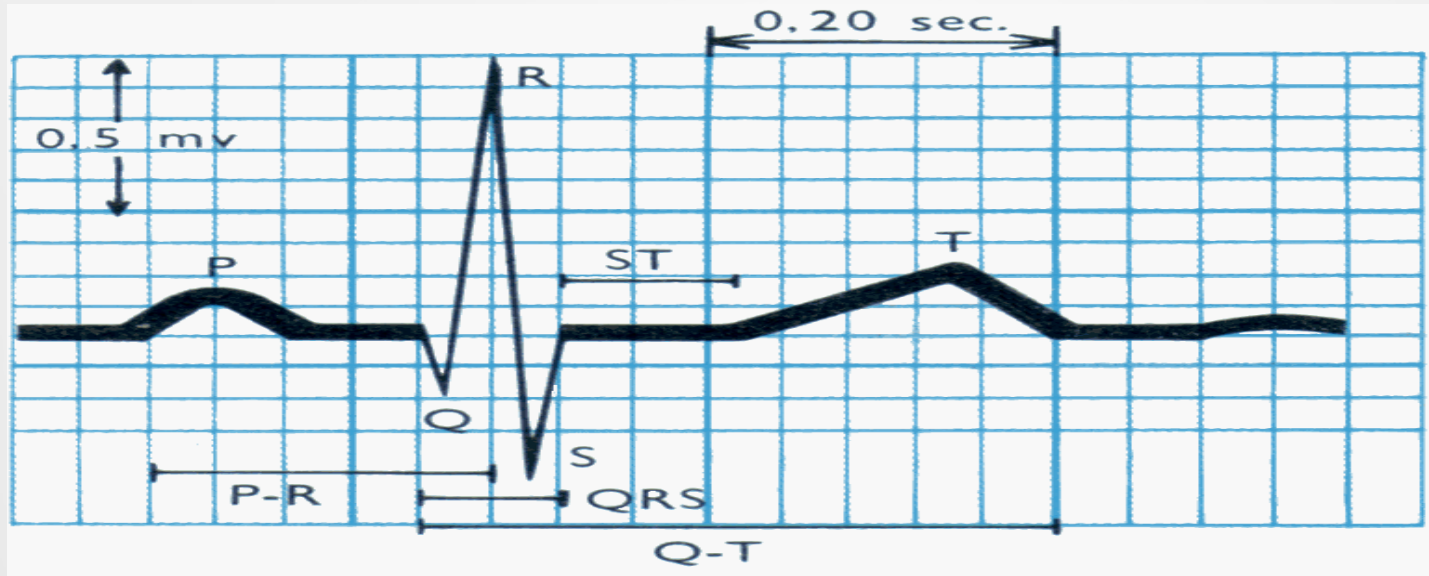
The Purkinje fibres transmit the impulse 5-6 times faster than through the intercalated discs so this ensures equal and efficient contraction of the ventricles.

- 
4. The ventricles contract from the apex, up and in, forcing blood towards the centre of the heart where it leaves via the arteries.
 5. Blood is prevented from re-entering the atria via the bicuspid and tricuspid valves

Cardiac Function



Electric Impulse (PQRST wave)



- The P wave is the electrical signature of the current that causes atrial contraction. Both the left and right atria contract simultaneously.
- The QRS complex corresponds to the current that causes contraction of the left and right ventricles, which is much more forceful than that of the atria and involves more muscle mass, thus resulting in a greater ECG deflection.
- The Q wave, when present, represents the small horizontal (left to right) current as the action potential travels through the interventricular septum.
- The R and S waves indicate contraction of the myocardium itself
- The T wave represents the repolarisation of the ventricles

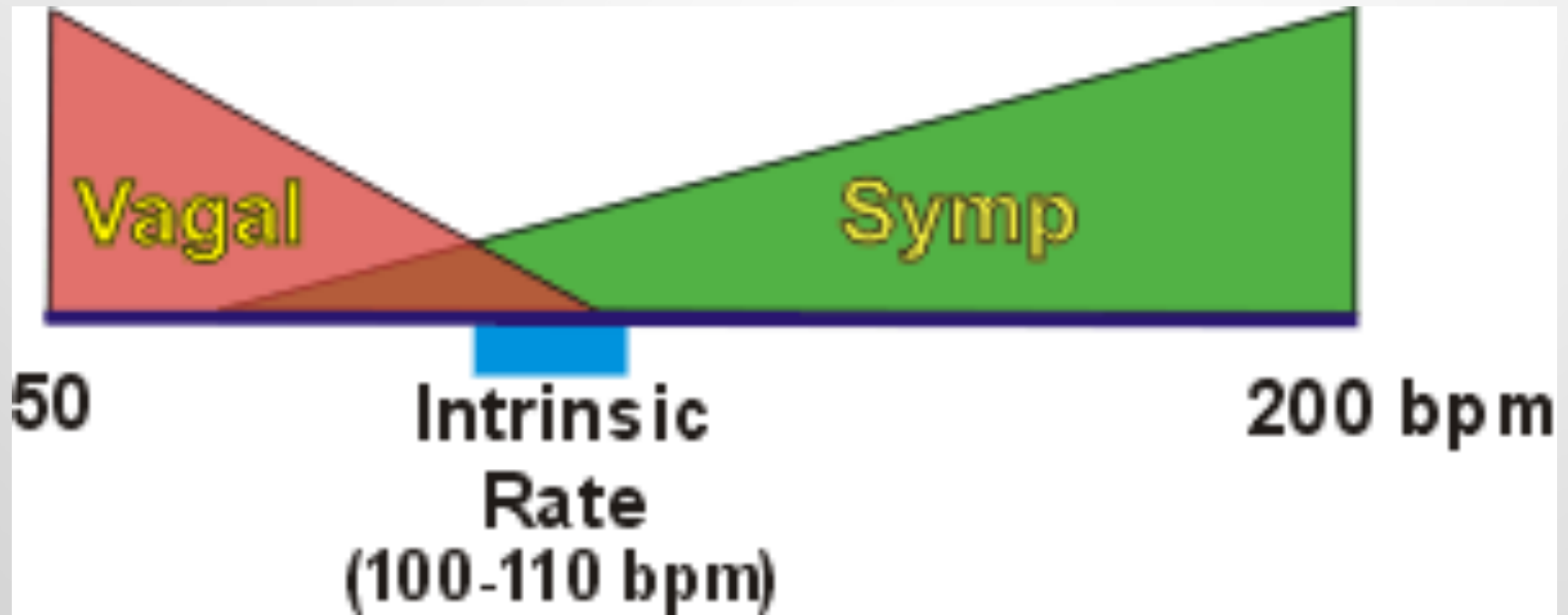
Control of Cardiac Function

- Chronotropic – change in heart rate
Hormonal and neural factors
- Inotropic – change in force of contraction
Mechanical and Hormonal
- Dromotropic – change in the conduction
- velocity of force

Control of Heart Rate (Chronotropic)

- Intrinsic - SA node is self initiating
(80b/min at rest)
- Extrinsic
 - Parasympathetic
 - Sympathetic
 - Hormonal (endocrine)

Control of Heart Rate



Nerve Control of heart Rate

This automatic rhythm of the heart can be altered by the autonomic nervous system.

1. The sympathetic nervous system, via cardiac nerves supply to the heart and most of the of the cardiac muscle. Stimulation via the cardiac beta-1 receptors causes the heart rate to increase and beat more forcefully.
2. The parasympathetic system via the 'Vagus nerve' also supplies the atria, and stimulation causes the heart rate to decrease (bradycardia).

Parasympathetic Control

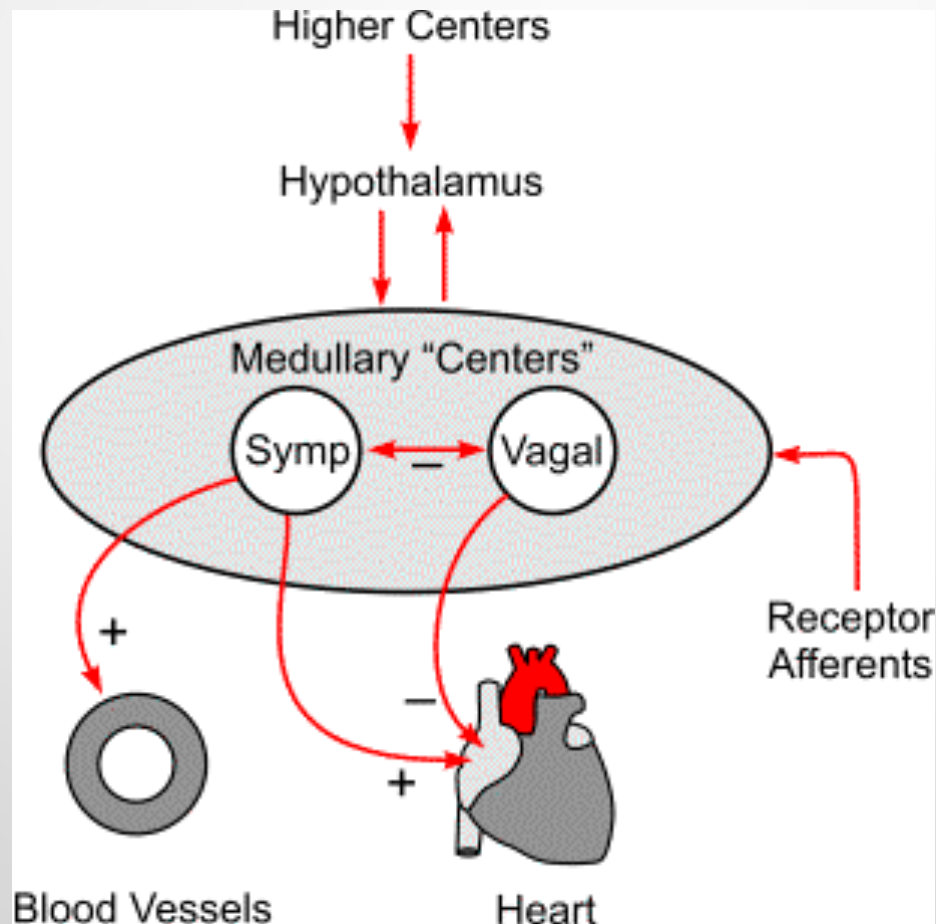
Vagus Nerve

- Acts to depress heart rate (20-30 bpm/min at rest) by increasing the levels of sodium required to generate an action potential.
- Reduces contractile force thereby reducing stroke volume.

Sympathetic control

- Caused by secretion of catecholamines which increase the leakiness to sodium and thereby increase the speed of the development of an action potential.
- Increases sensitivity of SA node reducing the delay in propagating action potential.

Autonomic regulation of Heart rate and circulation



Neural Reflex

Increased venous return stretches receptors in right atria and increases sympathetic tone and an instantaneous increase in heart rate

Increases in blood pressure in carotid and aortic arteries stimulates parasympathetic tone to decrease heart rate.

Current heart rate is a balance between these two system

Frank-Starling Law

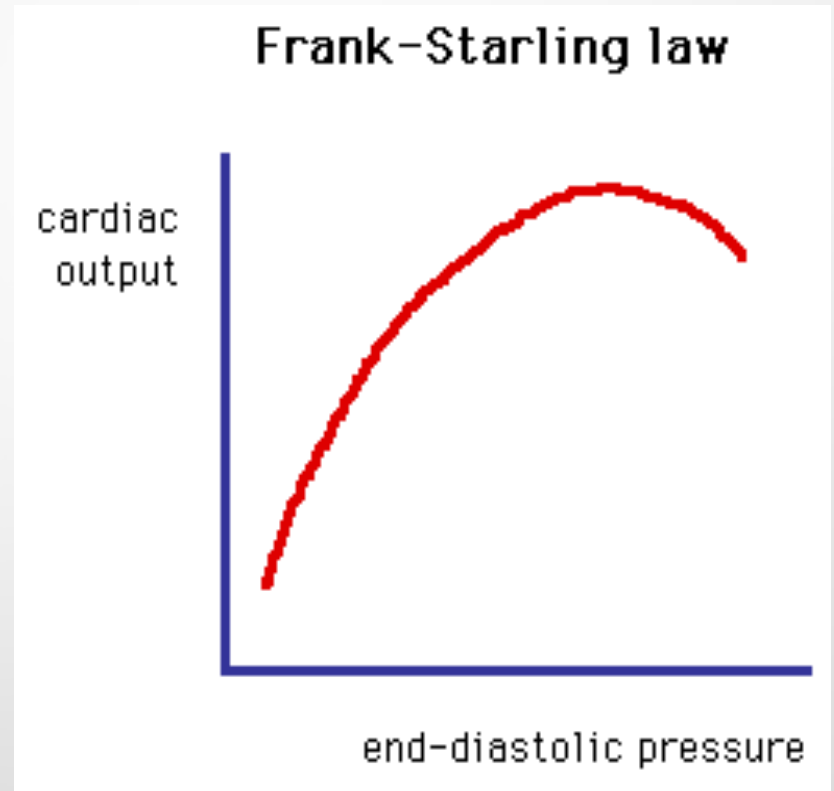


Force of velocity of contraction (Inotropic)

- Frank-Starling law of the heart

If the cardiac muscle is stretched it will contract in proportion to the elastic stretch

- Secretion of catecholamines increase the rate of energy *turn-over and thereby force/speed of contraction*



Blood Pressures

- **Atrial systole** is the contraction of the heart muscle of the left and right atria. Both atria contract at the same time.
- **Ventricular systole** is the contraction of the muscles of the left and right ventricles.
- **Cardiac Diastole** is the period of time when the heart relaxes after contraction in preparation for refilling with circulating blood

Blood Pressure

- Measured non-invasively using a sphygmomanometer usually on the brachial artery.
- Systolic pressure 110 – 140 mmHg
- Diastolic pressure 60 – 90 mmHg
- Shown as 120 / 80 mmHg

Factors that Affect Blood Pressure

Physiological factors:

- diet, exercise, disease, drugs,

physical factors:

- Heart rate - The higher the heart rate, the higher (potentially, assuming no change in stroke volume) the blood pressure.
- Volume of blood - The more blood present in the body, the higher the rate of blood return to the heart and the resulting cardiac output which increases force of contraction and thereby BP.
- Cardiac Output (Q) - heart rate multiplied by the stroke volume

Factors that Affect Blood Pressure

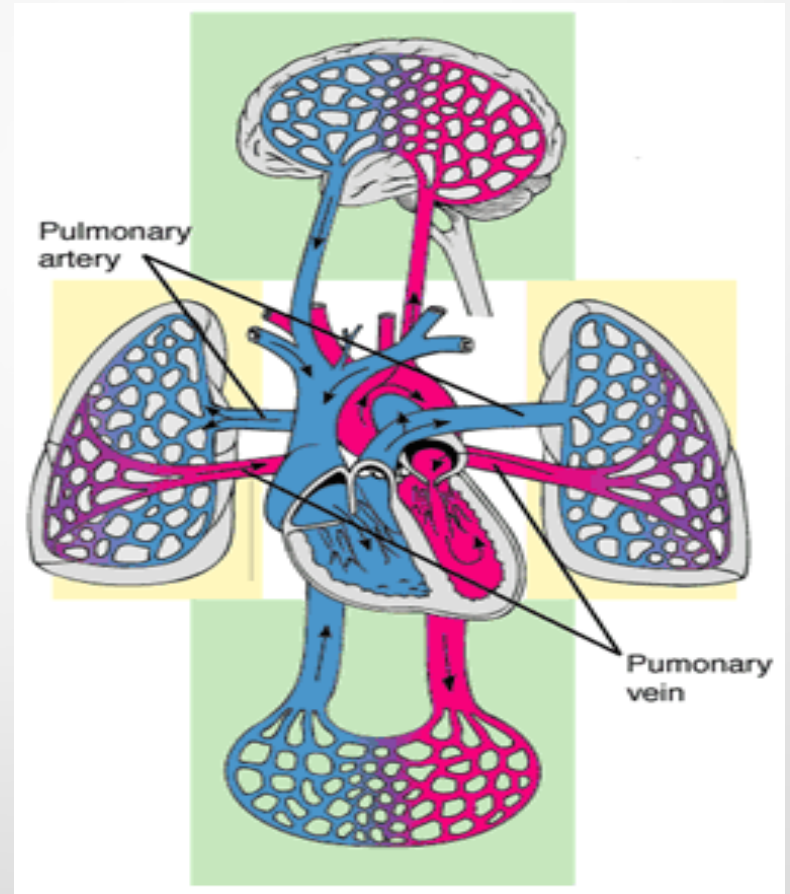
- Circulatory / peripheral Resistance - this is the resistance of the blood vessels. The higher the resistance, the higher the blood pressure. Resistance is related to size (The larger the blood vessel, the lower the resistance), as well as the smoothness of the blood vessel walls. Smoothness is reduced by the build up of fatty deposits on the arterial walls. Substances called vasoconstrictors can reduce the size of blood vessels, thereby increasing blood pressure. Vasodilators (such as nitroglycerin) increase the size of blood vessels, thereby decreasing blood pressure.
- Viscosity, or thickness of the blood. If the blood gets thicker (dehydration), the result is an increase in blood pressure

Terminology of Cardiac Function

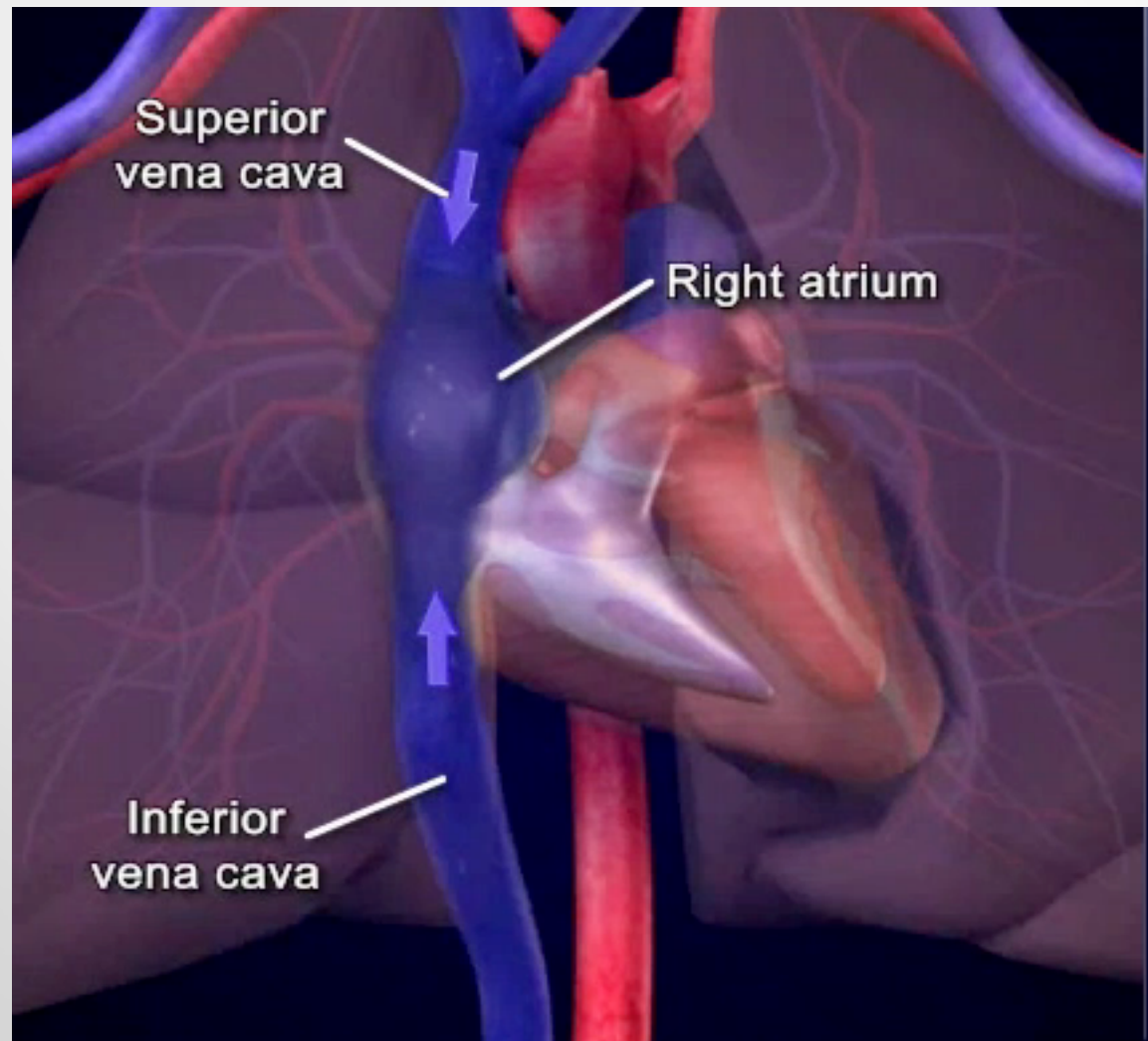
- Cardiac cycle
- Stroke volume
- Ejection fraction
- Heart rate
- Cardiac output
- Blood pressure
- Systole / Diastole

Nature of the systems

- 2 closed loop systems
- Pulmonary
- Systemic



Pulmonary Circulation



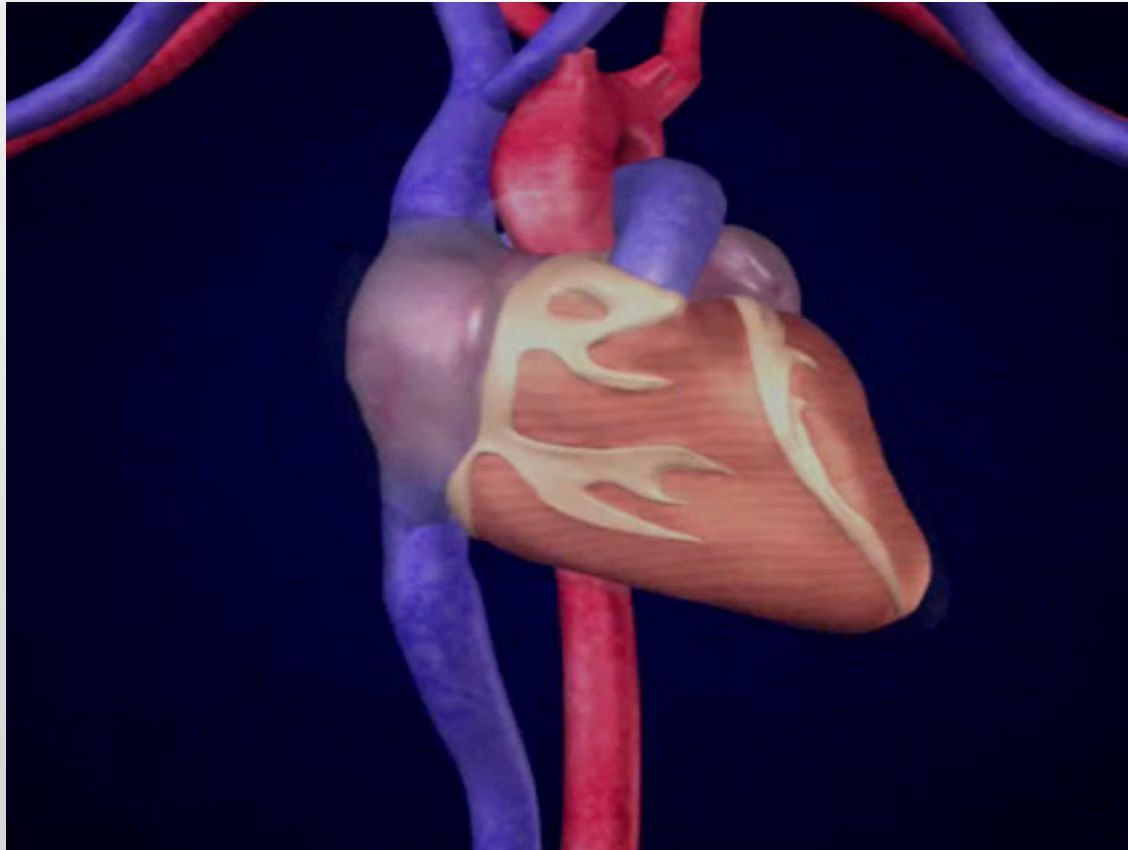
Systemic Circulation

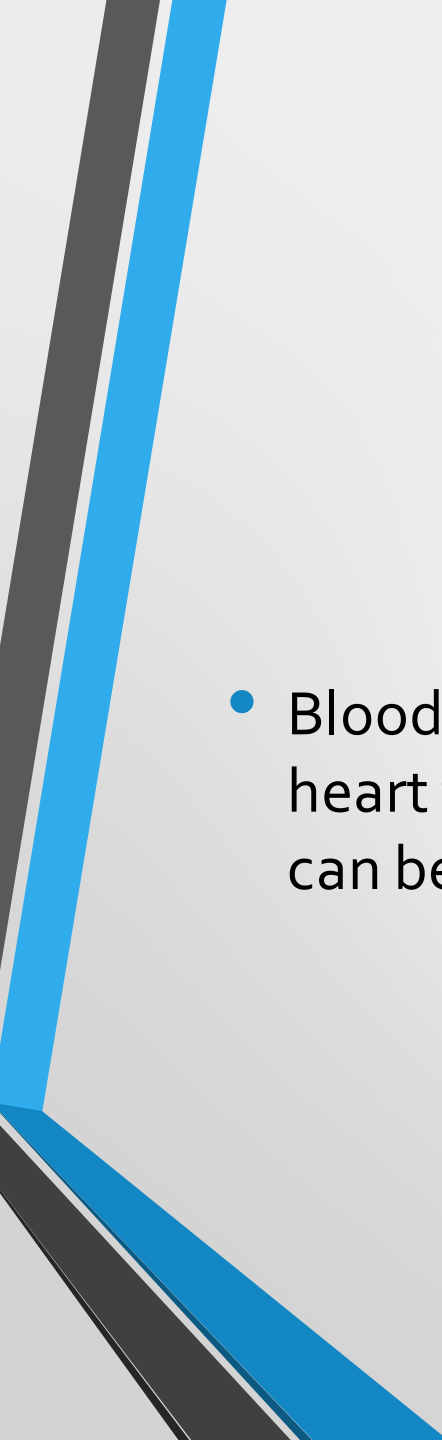
- Coronary
- Portal
- Muscle
- Skin

Coronary circulation

- The coronary arteries branch off the aorta and feed the cardiac muscle. During the relaxation of the heart muscle (diastole) blood flows through the coronary circulation supplying the myocardium (heart muscle).
- The coronary veins run beside the arteries and eventually drain into the coronary sinus and then directly into the right atrium.

Coronary Circulation





Portal circulation

- Blood from the stomach and intestine returns to the heart through the liver so that nutrient such as glucose can be stores. The blood is also cleansed in the liver.

Muscle circulation

- There is an enormous increase in muscle blood flow during exercise caused by the demand for oxygen and nutrients of the working muscle. The vessels supplying the active muscles undergo vasodilatation along side the vasoconstriction to those areas which do not have a large metabolic requirement during exercise. This process is called redistribution

Skin circulation

- The flow of blood to the skin increases in response to the thermoregulatory requirements of the body. In hot weather or during exercise the vessels in the skin dilate allowing heat to be lost. In the cold these vessels constrict retaining heat in the body