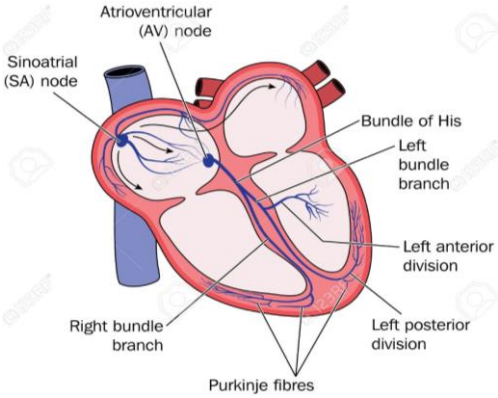
MPCC: 102. UNIT 2 – Cardiovascular System and Exercise:

2.1 Conduction System of the Heart:

The cardiac conduction system is a group of specialised cardiac muscle cell in the Wall of the heart that sends signals to the heart muscles causing it to contract. The main components of the cardiac conduction system are the **SA Node, AV Node, bundle of His, bundle branches and Purkinje fibres.**



Conduction over atrial muscle: Cardiac impulse originated at the SA Node is transmitted over both the Atria that cause the atrial muscles to contract.

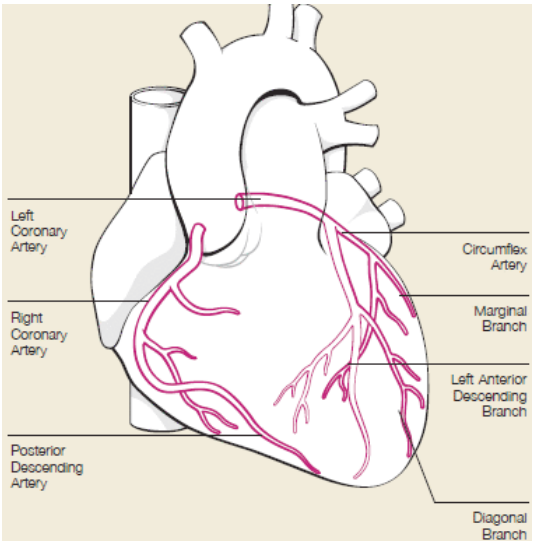
Conduction over AV Node: The SA Node sends impulses along certain pathway, causing the atria to contract when the electrical signal reaches them. The impulse then arrives at another node called Atrioventricular node or AV node. There is also a considerable delay of 0.07 to 0.1 sec. in transmission of impulse in the AV node before excitation spread over the ventricle. This AV nodal delay allows the atrial systole to complete before the ventricle is excited.

Conduction over bundle of His: beyond the AV region, the impulse is transmitted along the bundle branch at a higher velocity (4-5 metre/sec.).

Conduction through Perkinje system: Impulse after passing through the right and left bundle branches passes into the Perkinje fibres and also its multiple ramifications with in the sub-endocardial surfaces of both the ventricles.

Conduction through ventricular muscles: After mid septal activation from the left to right direction the impulse comes down the septum to the apex of the heart and next portion of the myocardium.

- **Blood Supply to the Heart:**



Blood is supplied to the heart by its own vascular system, called coronary circulation.

Coronary circulation is the circulation of blood in the blood vessels that supply the heart muscle (myocardium). Coronary arteries supply oxygenated blood to the heart muscle, and cardiac veins drain away the blood once it has been deoxygenated.

The aorta branches off into two main coronary blood vessels, called coronary arteries, branch off into smaller arteries, which supply oxygen-rich blood to the entire heart muscle.

Function of Cardiac veins: The vessels that remove the deoxygenated blood from the heart muscle are known as cardiac veins. These include the great cardiac vein, the middle cardiac vein, the small cardiac vein, the smallest cardiac veins, and the anterior cardiac veins. Cardiac veins carry deoxygenated blood from the myocardium to the right atrium. Most of the blood of the coronary veins returns through the coronary sinus.

- **Stroke Volume (SV):**

Stroke Volume (**SV**) is the volume of blood pumped from the left ventricle per beat/stroke.

For the normal person the average range is 70 ml. Its value is obtained by subtracting end-systolic volume (ESV) from end-diastolic volume (EDV) for a given ventricle.

EDV (100ml) – ESV (30ml) = SV (70ml)

- **Major factors influencing stroke volume –**
  - Heart size,
  - Contractility,
  - Duration of contraction,
  - Exercise: Prolonged aerobic exercise training ↑ stroke volume,
  - Preload (EDV): Stroke volume is intrinsically controlled by preloads (the degree to which the ventricles are stretched prior to contracting). Venous return ↑ preload / stroke volume ↑.
  - Afterload: Afterload reduces stroke volume.

- **Cardiac output:**

Cardiac output is the volume of blood pumped from the left ventricle in one minute.

Cardiac output is the product of the **heart** rate (HR), or the number of **heart** beats per minute (bpm), The normal range for cardiac output is about 4 to 8 L/min, **CO = HR × SV**

If a patient's stroke volume is 70 mL with each contraction and his heart rate is 72 beats/minute, his cardiac output is 5,040 mL/minute (or 5 L/minute).

HR x SV = CO	**Rest**	**Exercise**
Untrained	70bpm x 71.4ml = **5000ml/5lit**.	200bpm x 100ml = **20,000ml/20lit.**
Trained	45bpm x 111.1ml = **5000ml/5lit.**	200bpm x 200ml = **40,000ml/40lit.**

- **Factors affect cardiac output:**
  - Metabolic rate (Directly proportional)
  - Body surface area (Directly proportional)
  - Body weight (Directly proportional)
  - Muscular exercise
  - Posture
  - Age
  - Sex

2.2 Blood Flow at rest and during exercise:

Blood flow is movement of blood through a blood vessel, tissue or organ. Blood flow is denoted in term of volume of blood flowing in unit time. Ventricular contraction is responsible for the blood flow from major arteries and result in flow of blood from higher pressure region to lower pressure region.

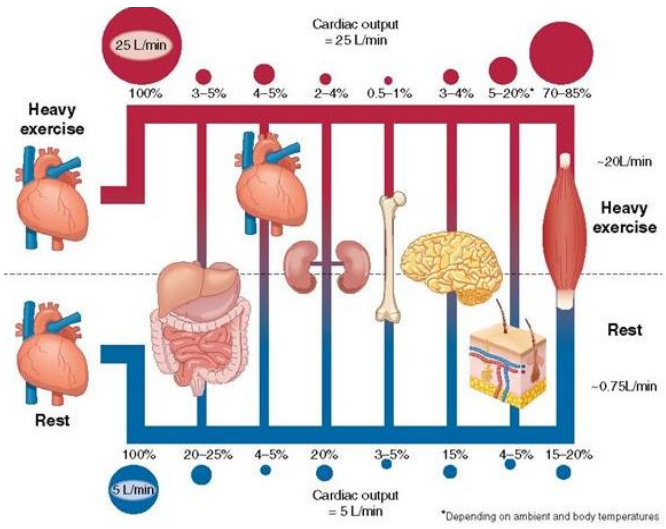
Blood flow to the various body tissue varies considerable depending on the immediate needs of a specific tissues compared with those of other area of the body.

Maximum amount of blood (85%) usually flows to our visceral organ in a resting state but when we start exercising then this maximum amount of blood flows to our skeletal muscles. This redirection of blood flow is caused by a mechanism (or process) called the vascular shunt mechanism.

Blood Flow at rest: At rest only between 15 to 20% of total systemic flows is distributed to the skeletal muscles, the majority goes to the visceral organs (Gastrointestinal tract, liver, spleen and Kidneys), the heart and the brain. Distribution of blood results from r**eflex vasoconstriction** of the arterioles supplying the inactive area of the body specially those of the visceral organ and skin. **Reflex vasodilation** of the arterioles supplying the active skeletal muscles, particularly before and at the very beginning of exercise.

At rest total systemic flow is distributed to the digestive system (22-25%), kidney (20%), Brain (15%), heart (4-5%), others (15%) and skeletal muscles (15- 20%) out of 5 litres per minute.

During exercise: However, during exercise there is a redistribution of blood flow, so that the active muscles receive the greatest proportion of cardiac output. In fact during maximal exercise of working muscles may receive as much as 85 to 90% of the total blood flow. This means that with a cardiac output of 30 litres per minute more than 25 litres of blood would go to the working muscles during maximum exercise. **Vasodilation** in the active muscles caused by increases in local temperature, CO_2 and lactic acid levels and lack of O_2, particularly as the exercise continues. Blood flow to the heart increases during exercise as a result of vasodilation and increase more working capacity of the heart, whereas that to the brain is maintained at testing levels.



During exercise this flow is redistributed to the digestive system (3-5%), kidney (2-4%), Brain (3-4%), other (2%) and skeletal muscles (80-85%) out of 20 to 25 litres per minute.

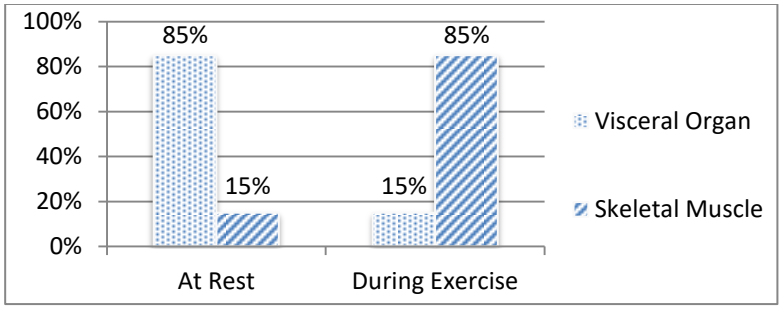


Fig: Distribution of blood at rest and during exercise.

2.3 Heart rate:

Heart rate is the number of heartbeats per unit of time, usually per minute. Rhythmic contraction and relaxation of the ventricle of the heart is known as heart rate. Heart rate is the speed of the Heartbeat measured by the number of contraction (beat) of the heart for minutes (bpm). **Normally in human sedentary adult males' heart rate is 72 beats per minute.**

The heart rate is based on the number of contractions of the ventricles (the lower chambers of the heart). The heart rate may be too fast (tachycardia) or too slow (bradycardia).

- **Factors Affecting Heart Rate:**

There are certain factors affecting heart rate. Such as -

1. **Posture**: The body position has a definite effect upon the heart rate. It appears that the typical response from the lying to the standing position is an increase around 10 to 12 beat per minute.
2. **Age**: Maximum heart rate decreases with age.
3. **Sex**: Females have higher resting heart rate than males. Adult female 84 beats per minute, adult male 78 beats per minute.
4. **Emotions and anxiety**: Rise of heart rate due to psychological reason.
5. **Exercise**: During Exercise the Heart Rate increases but exercise decreases the resting HR.
6. **Environmental factor**: The influence of environmental factor on heart functions is that a high temperature and altitude may greatly increase heart rate.
7. **Body Temperature**: With increase in the body temperature above normal, the heart rate increases. Conversely with decrease in temperature, the rate slows until a temperature of about $26^{o}C$ is reached.
8. **Terrain**: Walk or run uphill and your HR increases. Walk or run downhill and your HR decreases.
9. **Wind**: Walking or running with the wind at your back is easy, therefore HR decreases. Walking or running into the wind is more difficult HR increases.
10. **Dehydration**: As you become increasingly dehydrated during a long walk, hike, or run, your blood becomes thicker and waste products build up in bloodstream. Your heart will work harder to maintain constant cardiac output. A fluid loss of 3% of body weight increases pulse rate because of decrease in circulating blood volume.
11. **Smoking**: It has been observed that smoking even one cigarette significantly increases the resting heart rate.
12. **Diminishing glycogen stores** — your muscles primary fuel source. As the fuel depletes, in order to maintain the same walking or running pace, your HR rises.
13. **Nutrition**: Insufficient nutrition increases Heart rate.
14. **Sleep**: Insufficient sleep increases Heart rate.
15. **Recovery**: Insufficient recovery after a long hike, run, or other hard work out increases Heart rate.
16. **Illness**: Recent illness or a signal of impending illness raises Heart rate.
17. **Medication** – depending upon the medication, heart rate can either decrease or increase.

- **Cardiac hypertrophy:**

Cardiac hypertrophy is the abnormal enlargement, or thickening, of the heart muscle, resulting from increases in cardiomyocyte size and changes in other heart muscle components, such as extracellular matrix. Causes can be physiological - for example, the amount of exercise performed by an athlete or pathological - for example, as a result of hypertension or cardiac disease.

2.4 Effect of exercises and Training on Cardio vascular system:

During exercise circulatory system's most important function is transportation. The heart and blood vessel work to transport the oxygen from the lungs to muscles where it is needed.

A. Immediate effect:

1. **Heart rate:** The heart rate response is directly proportional and linear to the intensity of exercise. Heart rate increases from around 70 beats per minute to up to 200 beats per minute.
2. **Stroke volume**: Stroke volume increases with increasing rates of work but only up to exercise intensities between 40% and 60% of maximal capacity. Stroke volume the volume of blood increases from around 70ml to around 120 ml. In highly trained athletes' stroke volume can reach 200 ml./beat.
3. **Cardiac output**: During submaximal exercise between (40-60% of maximum capacity) cardiac output in trained athletes may be increased to 40 litres per minute, whereas untrained subjects may attend outputs of about 20 litres per minute. Cardiac output of untrained person is 40,000 ml. (200beats x 200ml.) and Cardiac output of untrained person is 20,000 ml. (200beats x 100ml.)
4. **Vasodilation:** The arteries respond to the body increased demands by widening slightly to allow more blood to pass through them.
5. **Blood Pressure**: During exercise blood pressure increases linearly as a result of an increase in cardiac output. The exercise affects on systolic blood pressure is much more then diastolic or mean pressure. In endurance type of training systolic blood pressure increases in direct proportion to increased exercise intensity. Systolic pressure of 120 mmHg at rest can exceed 200 mmHg at exhaustion.
6. **Blood Flow**: during maximal exercise of working muscles may receive as much as 85 to 90% of the total blood flow.
7. **Blood Glucose**: Percentage of Blood Glucose decrease. But in some cases moderate intensity of exercise (1500m run) blood glucose increases due to psychological effect.

B. Long term Effect:

1. **Cardiac hypertrophy –** The wall of the heart become thicker and stronger.
2. **Bradycardia**: Resting heart rate gets slower expected heart rate, generally beating fewer than 60 beats per minute.
3. Increases the **Stroke Volume** in resting condition.
4. The **heart** becomes bigger.
5. **R.B.C., Haemoglobin (myoglobin)** and **Total Blood Volume** increases.
6. Training also results in new **Capillaries** growing to improve the supply of blood to the muscle.