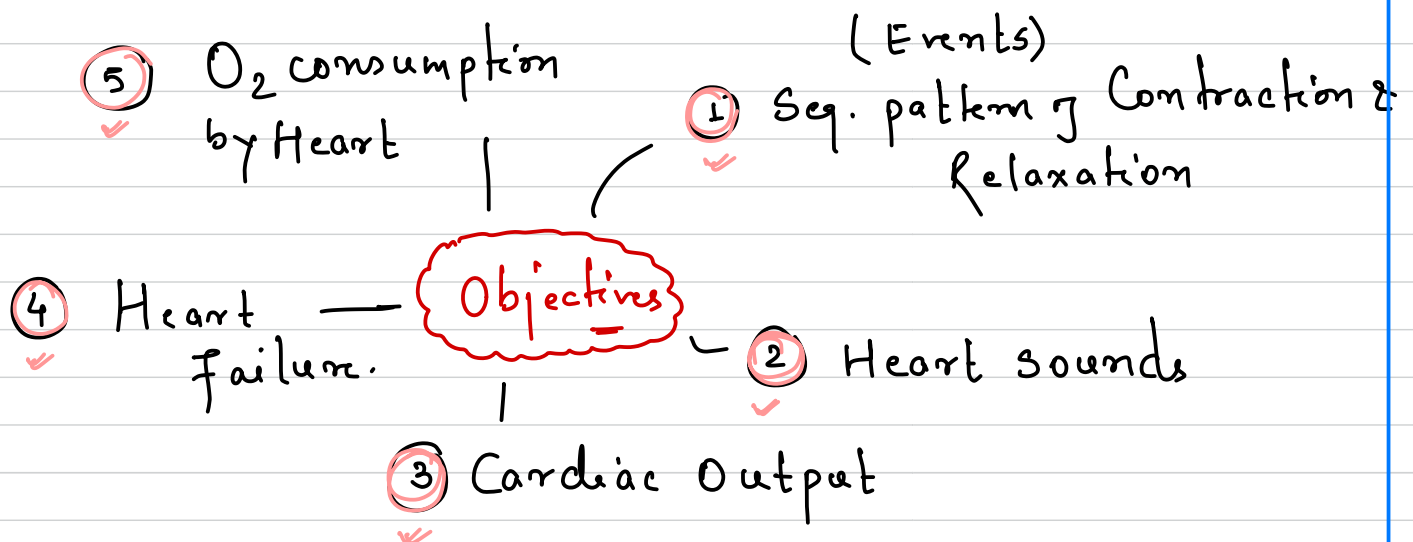


'Heart As a Pump'



obj ①

Events of Cardiac Cycle

• Late diastole:

- Blood flow into heart throughout diastole, filling atria and ventricles.
- About 70% of ventricular filling occurs passively during diastole.

• Ventricle systole:

- AV valve closes
- Ventricular muscle shortens relatively little but intra-ventricular pressure rises sharply.

• Atrial systole:

- Contraction of atria propels some additional blood into the ventricles.

- During this period, pressure in
Aorta $\Rightarrow$ 80 mm Hg
Pulmonary artery $\Rightarrow$ 10 mm Hg

- When aortic & pulmonary valves open, the phase of Ventricular ejection begins.
- Ejection is rapid at first, slowing down as systole progresses.
- Peak value of Pressure,
 - Left $\Rightarrow 120 \text{ mm Hg}$
 - Right $\Rightarrow 25 \text{ mm Hg}$.

- The amount of blood ejected $\Rightarrow 70-90 \text{ ml}$
- End-diastolic Ventricular Volume $\Rightarrow 130 \text{ ml}$
- 50 ml of blood remain into each ventricle. (End-systolic ventricular vol.)

• Early diastole :

- After the valves of Pulmonary and Aortic artery are closed, the pressure drops rapidly, during the period of Isovolumetric Ventricular Relaxation.
- As the ventricle pressure drops below that of Atrial, the AV valves open, and the rapid filling begins.
- The cycle continues again as late diastole.

• Thus Ejection fraction is about 65%.

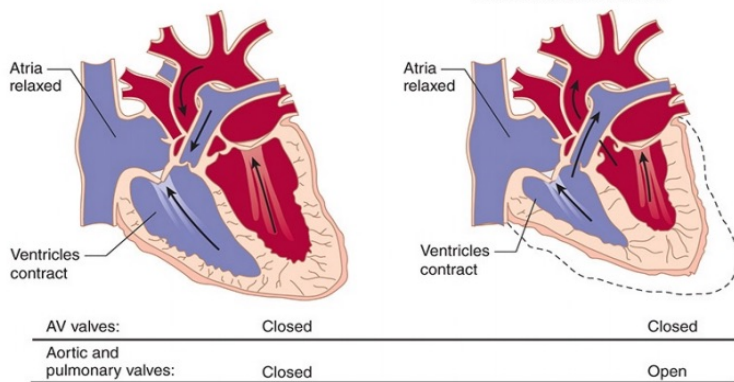
$$\left(\frac{\sim 80}{130} \right) \uparrow$$

A Systole

Isovolumetric ventricular contraction

Ventricular ejection

Blood flows out of ventricle



B Diastole

Isovolumetric ventricular relaxation

Ventricular filling

Blood flows into ventricles

Atrial contraction

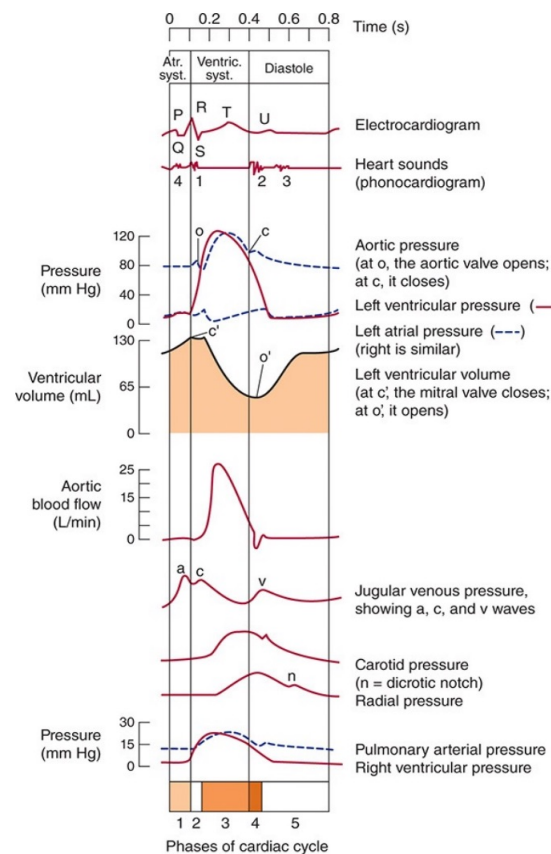
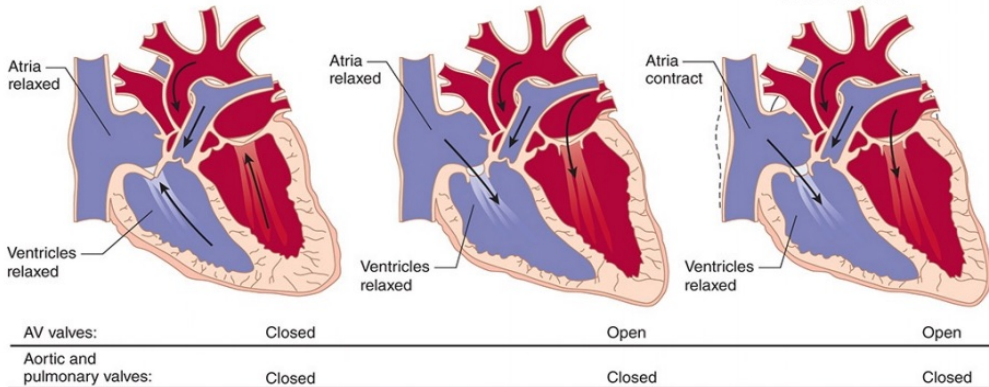


Fig- Events of Cardiac cycle.

FIGURE 30-1 Divisions of the cardiac cycle: A) systole and B) diastole. The phases of the cycle are identical in both halves of the heart. The direction in which the pressure difference favors flow is denoted by an arrow; note, however, that flow will not actually occur if a valve prevents it. AV, atrioventricular. Note that the rightmost panel of those shown in B corresponds to atrial systole, even though the cardiac cycle overall remains in diastole.

Timing

- Although events on two sides are similar, they are asynchronous.
- Right atrial systole precedes left atrial systole, whereas contraction of the Right ventricle starts after that of the left.
- Since pulmonary arterial pressure is lower than aortic pressure, right ventricular ejection begins before that of left.

- During expiration, the pulmonary and aortic valves close at same time, whereas during inspiration, the aortic valve closes slightly before than pulmonary valve.

Length of Systole & Diastole :-

- Cardiac muscle can contract and repolarise fast when heart beat is fast.

As : Duration of systole,
 0.27 s when 65 beats/min &
 0.16 s when 200 beats/min

	Heart Rate 75/min	Heart Rate 200/min	Skeletal Muscle
Duration, each cardiac cycle	0.80	0.30	...
Duration of systole	0.27	0.16	...
Duration of action potential	0.25	0.15	0.007
Duration of absolute refractory period	0.20	0.13	0.004
Duration of relative refractory period	0.05	0.02	0.003
Duration of diastole	0.53	0.14	...

^aAll values are in seconds.

- Diastole is even more affected as, 0.62 s in 65 beats/min } This is important as it is during diastole, heart muscle rests.
 0.14 s in 200 beats/min

- As Cardiac muscle has prolonged Action Potential, it can not contract in response to other stimuli until near the end of initial contraction

↓
 Thus Cardiac muscle can not be tetanized as skeletal muscle.

- Coronary blood flow to subendocardial portions of left ventricle.

- And most of Ventricular filling occurs in diastole.

* Cardiac Output will fall if Heart Rate ↑

- Highest rate at which ventricles can contract is theoretically about 400/min; but in Adults the AV node will not conduct more than 230 impulses/min due to its long refractory period.
- A ventricular contraction > 230/min is seen only in **Paroxysmal ventricular tachycardia**.

Obj.
(2)

Heart Sounds

- There are normally two sounds heard through a stethoscope during each cardiac cycle.

(1) **LUB** - First sound

- Low
- Prolonged
- Due to closure of AV valves at the start of ventricular systole.
- last 0.15 sec, $f \rightarrow 25-45$ Hz

(2) **DUB** - Second sound

- Shorter
- high pitched
- Closure of Aortic & Pulmonary valve.
- last 0.12s, $f \rightarrow 50$ Hz

(3) **Third sound** - Soft

- low pitched
- In young individuals
- About $1/3^{\text{rd}}$ of way through diastole due to inrush of blood.

- last 0.1s

< 4) Fourth sound

- Heard immediately before first sound.
- When Atrial pressure is high and / or ventricle is stiff in case of Ventricular hypertrophy.
- It is heard due to ventricular filling.
- Rarely heard in Normal adults.

Murmurs:

- Murmurs / bruits - abnormal sounds heard in various parts of vascular system.
- Murmur → normally for heart
bruit → normally outside heart like in blood vessels.
- The major cause of heart murmur is Disease of heart valve.
As, stenosis (orifice of valve is narrowed)
Regurgitation (blood flowing backward) due to incompetent valve.
- In patients with congenital interventricular septal defects, flow from left to right ventricle causes a systolic murmur.
- Soft murmur in interatrial septal defects.
↳ also in children with no cardiac defects.
- Systolic murmur → Anemic patients with low blood viscosity.

obj (3)

Cardiac Output

- The output of heart/time.
- Cardiac output = Stroke volume $\times$ heart beat
 $= 70 \text{ mL} \times 72 \text{ beats/min}$
 $= 5 \text{ L/min}$
- Cardiac Output in Various Condition:

Condition or Factor ^a	
No change	Sleep Moderate changes in environmental temperature
Increase	Anxiety and excitement (50–100%) Eating (30%) Exercise (up to 700%) High environmental temperature Pregnancy Epinephrine
Decrease	Sitting or standing from lying position (20–30%) Rapid arrhythmias Heart disease

obj (4)

Heart failure

- Systolic failure
 - The end-systolic ventricular volume $\uparrow$
 - Ejection fraction falls from 65% to as low as 20%.
 - Due to activation of genes that cause cardiac myocytes to hypertrophy & thickening of ventricular wall.
- Diastolic failure
 - Ejection fraction is maintained.
 - Elasticity of myocardium is reduced so filling during diastole is reduced.
 - Leads to inadequate cardiac output.

Treatment of heart failure is aimed at improving cardiac contractility, treating the symptoms, and decreasing the load on the heart. Currently, the most effective treatment in general use is inhibition of the production of angiotensin II with angiotensin-converting enzyme (ACE) inhibitors. Blockade of the effects of angiotensin II on AT_1 receptors with nonpeptide antagonists is also of value. Blocking the production of angiotensin II or its effects also reduces the circulating aldosterone level and decreases blood pressure, reducing the afterload against which the heart pumps. The effects of aldosterone can be further reduced by administering aldosterone receptor blockers. Reducing venous tone with nitrates or hydralazine increases venous capacity so that the amount of blood returned to the heart is reduced, lowering the preload. Diuretics reduce the fluid overload. Drugs that block β -adrenergic receptors have been shown to decrease mortality and morbidity. Digitalis derivatives such as digoxin have classically been used to treat heart failure because of their ability to increase stores of intracellular Ca^{2+} and hence exert a positive inotropic effect, but they are now used in a secondary role to treat systolic dysfunction and slow the ventricular rate in patients with atrial fibrillation.

Objective
⑤

Oxygen Consumption by Heart

- Basal O_2 consumption by myocardium is $\sim 2 \text{ ml}/100 \text{ g}/\text{min}$.
- Beating heart O_2 consumption is $\sim 9 \text{ ml}/100 \text{ g}/\text{min}$.
- Consumption of O_2 by heart is determined by ;
 - (a) Intramyocardial tension
 - (b) The contractile state of myocardium
 - (c) Heart Rate.
- Heart Rate $\uparrow$, O_2 consumption $\uparrow$

CARDIAC PRESSURES

