CARDIAC CYCLE

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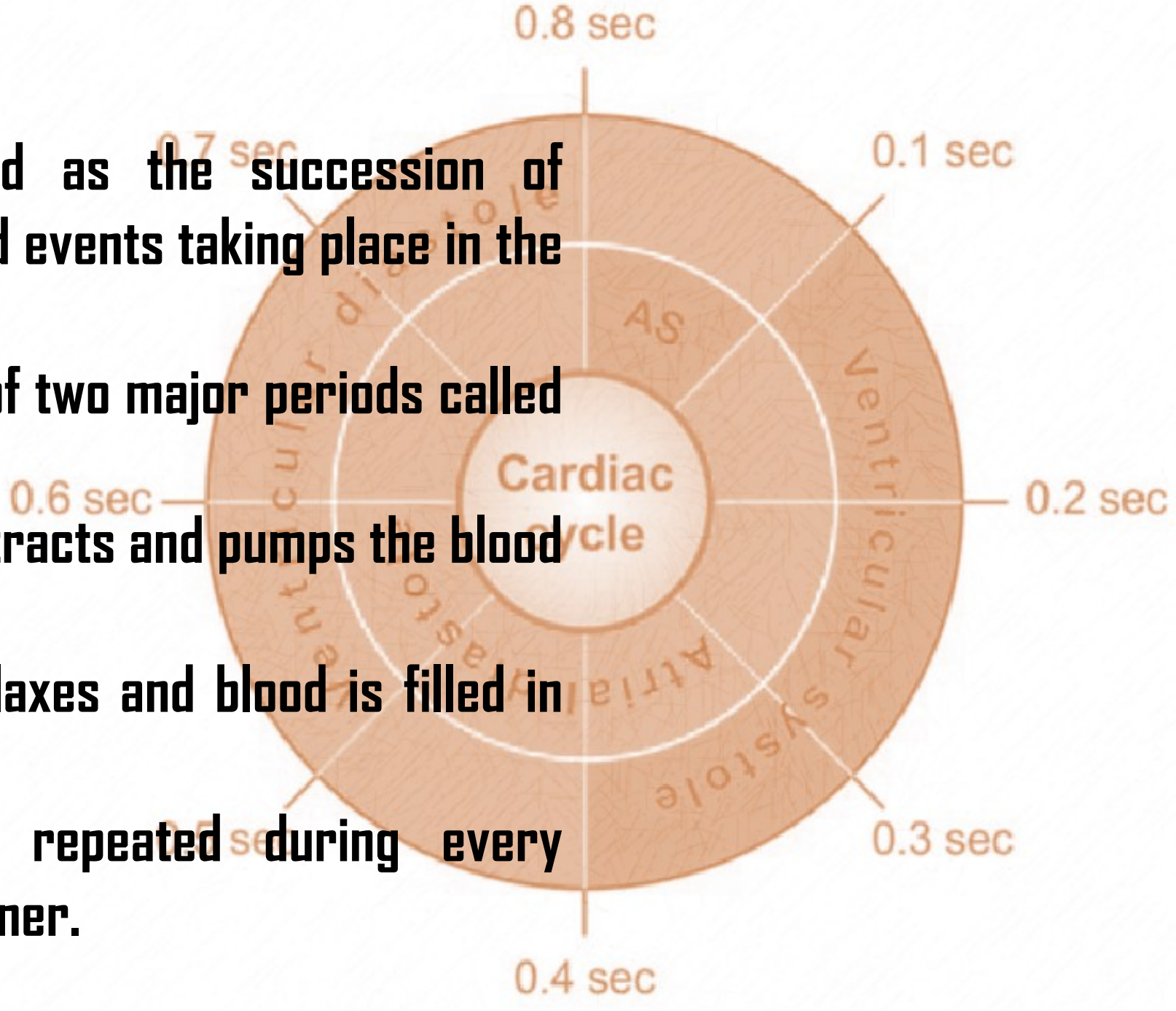
INTRODUCTION

- Cardiac cycle is defined as the succession of (sequence of) coordinated events taking place in the heart during each beat.
- Each heartbeat consists of two major periods called systole and diastole.
- During systole, heart contracts and pumps the blood through arteries.
- During diastole, heart relaxes and blood is filled in the heart.
- All these changes are repeated during every heartbeat, in a cyclic manner.



DIVISIONS AND DURATION OF CARDIAC CYCLE

- When the heart beats at a normal rate of 72/minute, duration of each cardiac cycle is about 0.8 second.
- Events of cardiac cycle are classified into two:

ATRIAL EVENTS

- Atrial events are divided into two divisions:

1. Atrial systole = 0.11 (0.1) sec
2. Atrial diastole = 0.69 (0.7) sec

VENTRICULAR EVENTS

- Ventricular events are divided into two divisions:

1. Ventricular systole = 0.27 (0.3) sec
2. Ventricular diastole = 0.53 (0.5) sec

- In clinical practice, the term 'systole' refers to ventricular systole and 'diastole' refers to ventricular diastole.
- Ventricular systole is divided into two subdivisions and ventricular diastole is divided into five subdivisions.

1. VENTRICULAR SYSTOLE

i. Isometric contraction = 0.05
ii. Ejection period = 0.22

Time (second) 0.27

2. VENTRICULAR DIASTOLE

i. Protodiastole = 0.04
ii. Isometric relaxation = 0.08
iii. Rapid filling = 0.11
iv. Slow filling = 0.19
v. Last rapid filling = 0.11

Time (second) 0.53

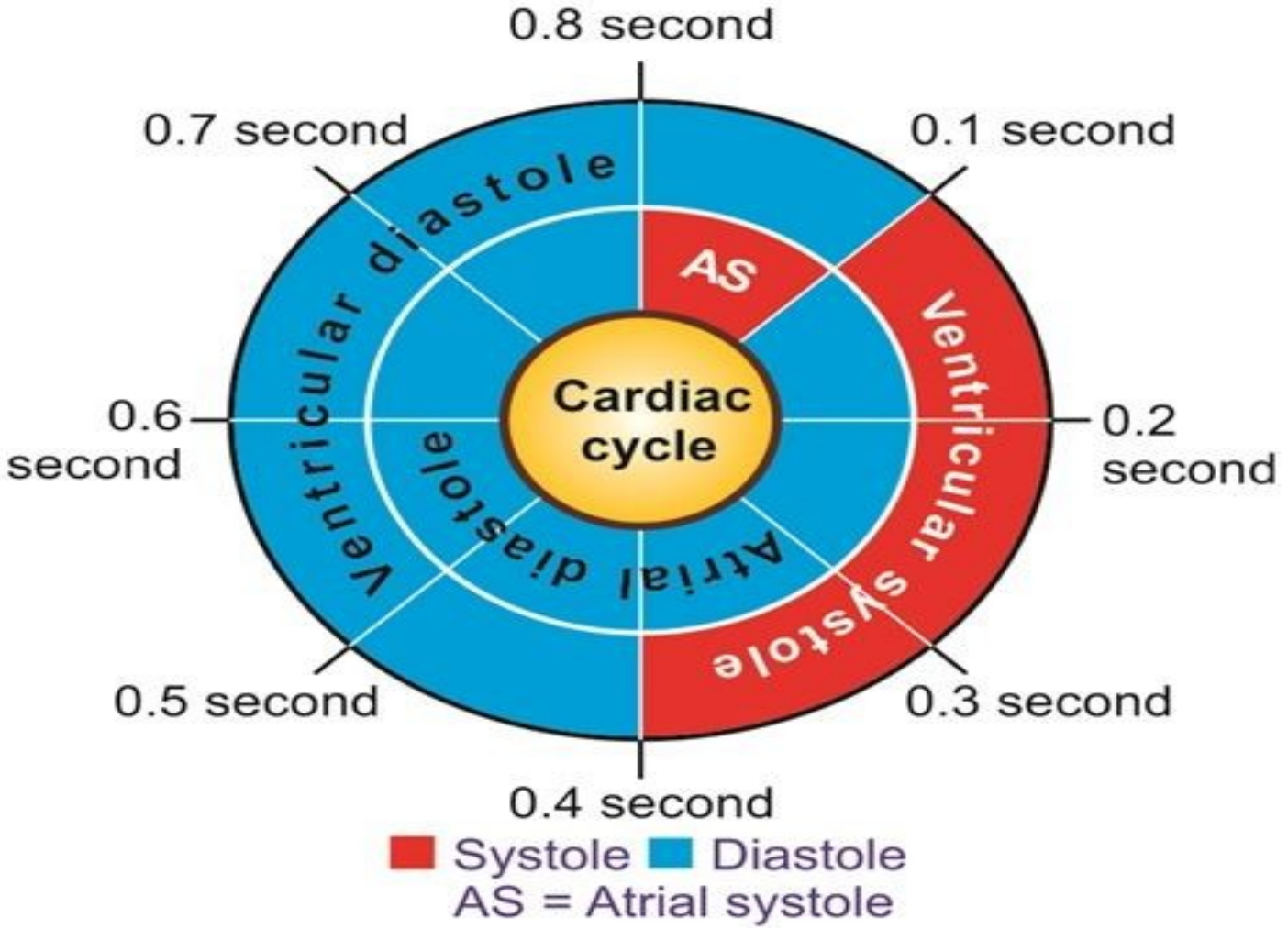


FIGURE : ATRIAL AND VENTRICULAR EVENTS OF CARDIAC CYCLE

ATRIAL SYSTOLE

- Atrial systole is also known as **last rapid filling phase** or **presystole.**
- It is usually considered as the last phase of ventricular diastole. Its duration is 0.11 second.
- During this period, only a small amount, i.e. 10% of blood is forced from atria into ventricles. Atrial systole is not essential for the maintenance of circulation.
- Many persons with atrial fibrillation survive for years, without suffering from circulatory insufficiency.
- However, such persons feel difficult to cope up with physical stress like exercise.

PRESSURE AND VOLUME CHANGES

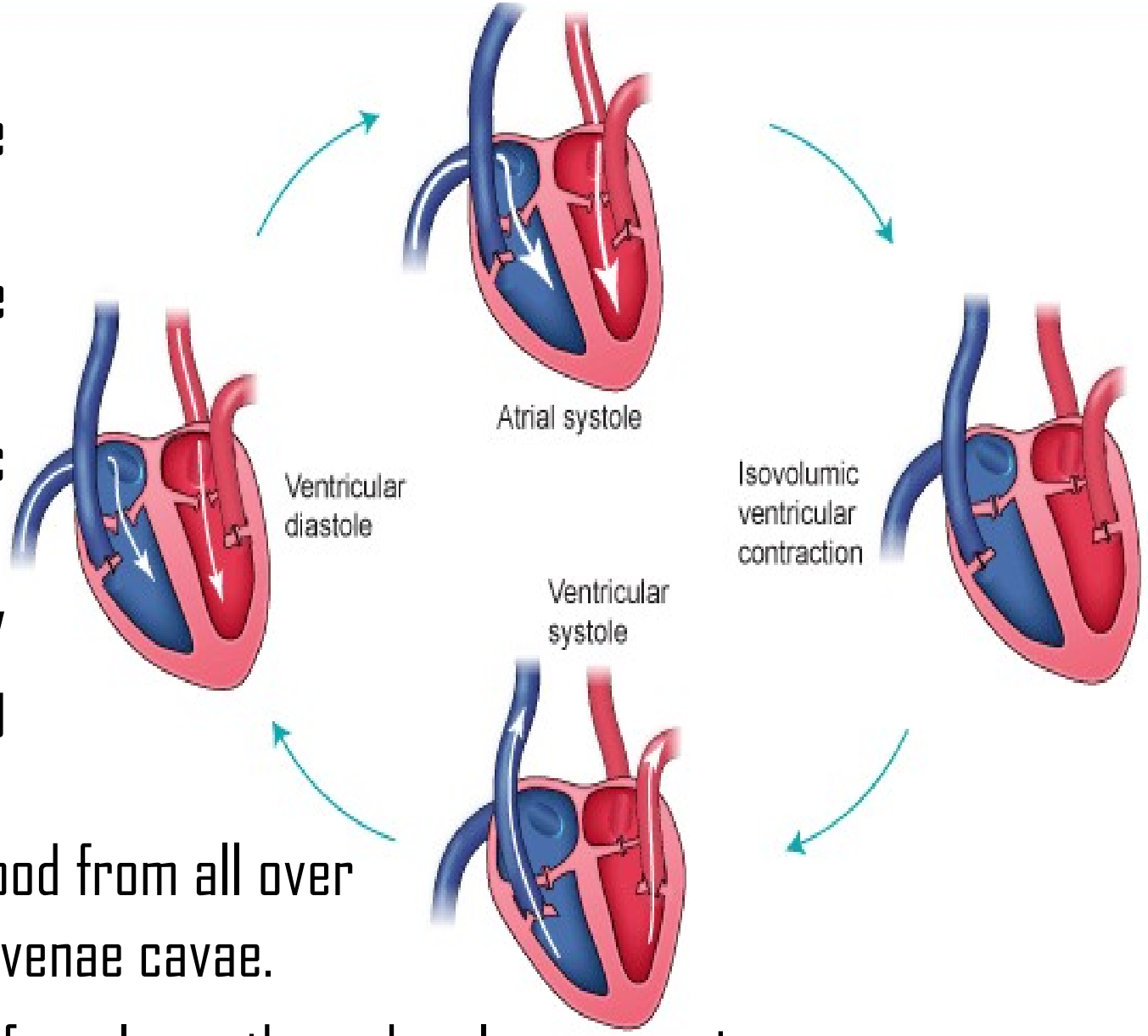
- During atrial systole, the intraatrial pressure increases.
- Intraventricular pressure and ventricular volume also increase but slightly.

FOURTH HEART SOUND

- Contraction of atrial musculature causes the production of fourth heart sound.

ATRIAL DIASTOLE

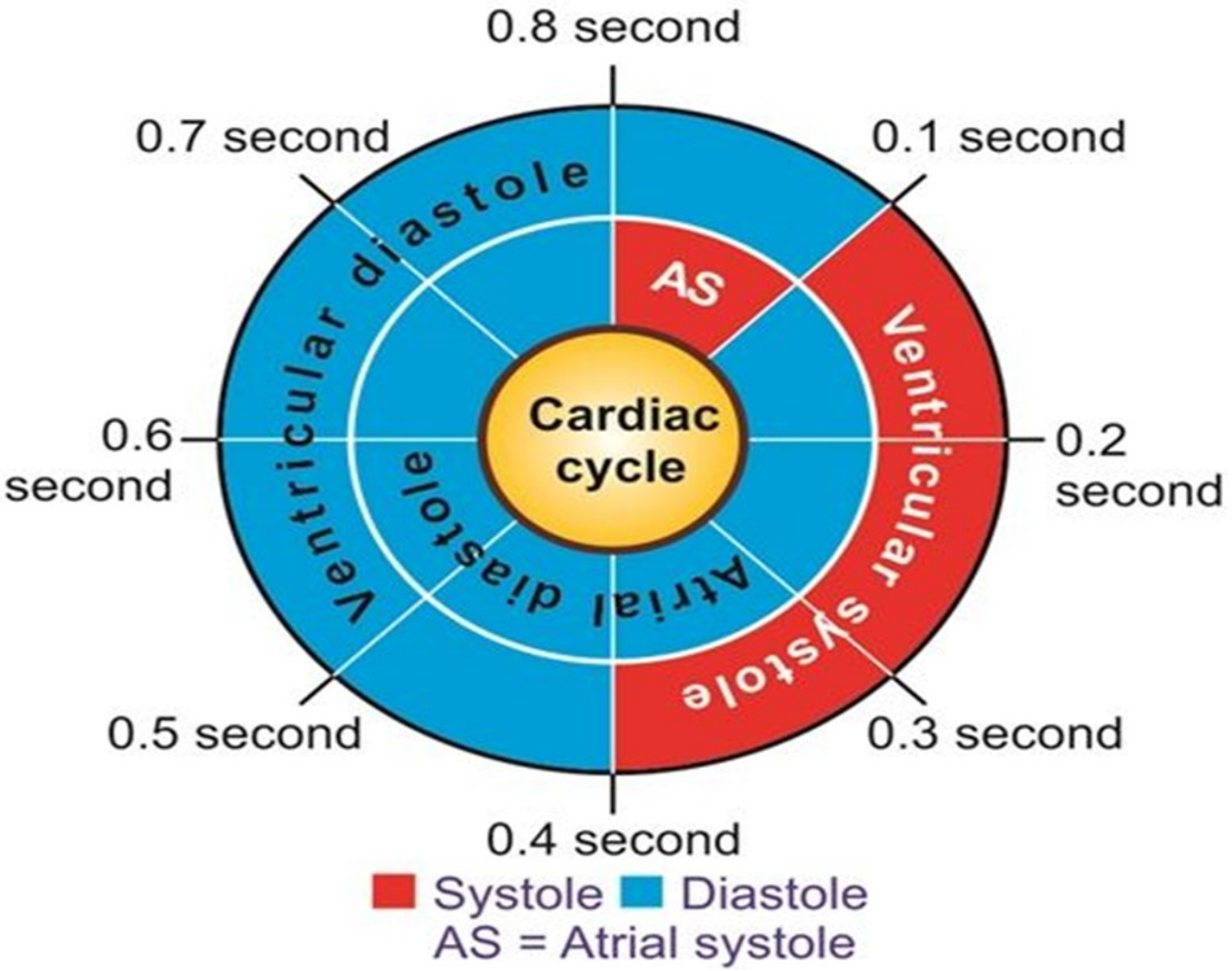
- After atrial systole, the atrial diastole starts.
- Simultaneously, ventricular systole also starts.
- Atrial diastole lasts for about 0.7 sec (accurate duration is 0.69 sec).
- This long atrial diastole is necessary because, this is the period during which atrial filling takes place.



- Right atrium receives deoxygenated blood from all over the body through superior and inferior venae cavae.
- Left atrium receives oxygenated blood from lungs through pulmonary veins.

ATRIAL EVENTS VS VENTRICULAR EVENTS

- Out of 0.7 sec of atrial diastole, first 0.3 sec (0.27 sec accurately) coincides with ventricular systole.
- Then, ventricular diastole starts and it lasts for about 0.5 sec (0.53 sec accurately).
- Later part of atrial diastole coincides with ventricular diastole for about 0.4 sec.
- So, the heart relaxes as a whole for 0.4 sec.



VENTRICULAR SYSTOLE

- Ventricular systole is divided into two subdivisions.

i. ISOMETRIC CONTRACTION PERIOD

- Isometric contraction period is the first phase of ventricular systole. It lasts for 0.05 second.
- Isometric contraction is characterized by increase in tension, without any change in the length of muscle fibers. So Isometric contraction is also called **isovolumetric contraction.**
- Immediately after atrial systole, the atrioventricular valves are closed due to increase in ventricular pressure. Semilunar valves are already closed.
- Now, ventricles contract as closed cavities, in such a way that there is no change in the volume of ventricular chambers or in the length of muscle fibers.
- Only the tension increases in ventricular musculature.

- Because of increased tension in ventricular musculature during isometric contraction, the pressure increases sharply inside the ventricles.

FIRST HEART SOUND

- Closure of atrioventricular valves at the beginning of this phase produces first heart sound.

SIGNIFICANCE OF ISOMETRIC CONTRACTION

- During isometric contraction period, the ventricular pressure increases greatly.
- When this pressure increases above the pressure in the aorta and pulmonary artery, the semilunar valves open.
- Thus, the pressure rise in ventricle, caused by isometric contraction is responsible for the **opening of semilunar valves,** leading to ejection of blood from the ventricles into aorta and pulmonary artery.

ii. EJECTION PERIOD

- Due to the opening of semilunar valves and isotonic contraction of ventricles, blood is ejected out of both the ventricles. Hence, this period is called ejection period.
- Duration of this period is 0.22 second.

Ejection period is of two stages:

1. First Stage or Rapid Ejection Period

- First stage starts immediately after the opening of semilunar valves. During this stage, a large amount of blood is rapidly ejected from both the ventricles.
- It lasts for 0.13 second.

2. Second Stage or Slow Ejection Period

- During this stage, the blood is ejected slowly with much less force.
- Duration of this period is 0.09 second.

END-SYSTOLIC VOLUME

- Ventricles are not emptied at the end of ejection period and some amount of blood remains in each ventricle.
- Amount of blood remaining in ventricles at the end of ejection period (i.e. at the end of systole) is called endsystolic volume.
- It is 60 to 80 mL per ventricle.

VENTRICULAR DIASTOLE

- ventricular diastole is divided into five subdivisions.

i. PROTODIASTOLE

- Protodiastole is the first stage of ventricular diastole, hence the name protodiastole.
- Duration of this period is 0.04 second.

- Due to the ejection of blood, the pressure in aorta and pulmonary artery increases and pressure in ventricles drops.
- When intraventricular pressure becomes less than the pressure in aorta and pulmonary artery, the semilunar valves close.
- Atrioventricular valves are already closed.
- No other change occurs in the heart during this period. Thus, protodiastole indicates only the end of systole and beginning of diastole.

SECOND HEART SOUND

- Closure of semilunar valves during this phase produces second heart sound.

ii. ISOMETRIC RELAXATION PERIOD

- Isometric relaxation is characterized by decrease in tension without any change in the length of muscle fibers. So Isometric relaxation of ventricular muscle is also called **isovolumetric relaxation.**

- During isometric relaxation period, once again all the valves of the heart are closed.
- Now, both the ventricles relax as closed cavities without any change in volume. So the intraventricular pressure decreases.
- Duration of isometric relaxation period is 0.08 second.

SIGNIFICANCE OF ISOMETRIC RELAXATION

- During isometric relaxation period, the ventricular pressure decreases greatly.
- When the ventricular pressure becomes less than the pressure in the atria, the atrioventricular valves open.
- Thus, the fall in pressure in the ventricles is responsible for the **opening of atrioventricular valves,** resulting in filling of ventricles.

iii. RAPID FILLING PHASE

- When atrionventricular valves are opened, there is a sudden rush of blood (which is accumulated in atria during atrial diastole) from atria into ventricles.

- So, this period is called the first rapid filling period.
- About 70% of filling takes place during this phase, which lasts for 0.11 second.

THIRD HEART SOUND

- Rushing of blood into ventricles during this phase causes production of third heart sound.

iv. SLOW FILLING PHASE

- After the sudden rush of blood, the ventricular filling becomes slow. Now, it is called the slow filling.
- It is also called **diastasis.**
- About 20% of filling occurs in this phase.
- Duration of slow filling phase is 0.19 second.

v. LAST RAPID FILLING PHASE

- Last rapid filling phase occurs because of atrial systole.
- After slow filling period, the atria contract and push a small amount of blood into ventricles.
- About 10% of ventricular filling takes place during this period.
- Flow of additional amount of blood into ventricle due to atrial systole is called **atrial kick.**

END-DIASTOLIC VOLUME

- End-diastolic volume is the amount of blood remaining in each ventricle at the end of diastole.
- It is about 130 to 150 mL per ventricle.

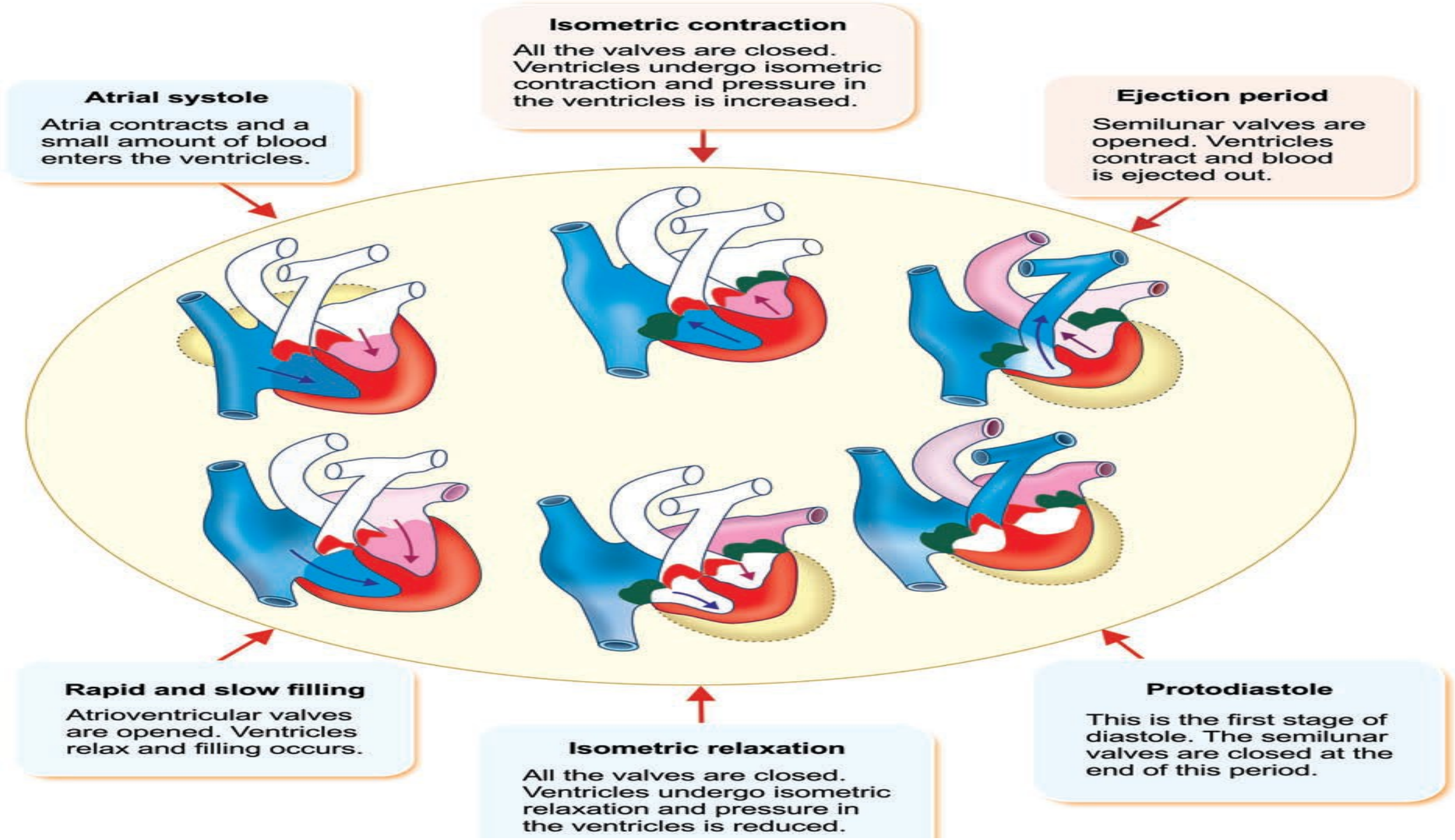


FIGURE : PHASES OF CARDIAC CYCLE

EJECTION FRACTION

- Ejection fraction refers to the fraction (or portion) of enddiastolic volume that is ejected out by each ventricle per beat.
- It is expressed by percentage.
- **End-diastolic volume** is the amount of blood remaining in each ventricle at the end of diastole. It is about 130 to 150 mL per ventricle.
- Amount of blood remaining in ventricles at the end of systole is called **End-systolic volume**. It is 60 to 80 mL per ventricle.
- The difference between **enddiastolic volume** and **endsystolic volume** is called **stroke volume**. It is about 70 mL per ventricle.
- It means From 130 to 150 mL of enddiastolic volume, 70 mL is ejected out by each ventricle (stroke volume).
- Normal ejection fraction is **60% to 65%**.

DETERMINATION OF EJECTION FRACTION

- Ejection fraction (Ef) is the stroke volume divided by enddiastolic volume expressed in percentage.
- Stroke volume (SV) is, enddiastolic volume (EDV) minus endsystolic volume (ESV).
- Ejection fraction is calculated as:

$$E_f = \frac{SV}{EDV} = \frac{EDV - ESV}{EDV}$$

Where,

Ef = Ejection fraction

SV = Stroke volume

EDV = Enddiastolic volume

ESV = Endsystolic volume

SIGNIFICANCE OF DETERMINING EJECTION FRACTION

- Ejection fraction is the measure of left ventricular function.
- Clinically, it is considered as an important index for assessing the ventricular contractility.
- Ejection fraction decreases in **myocardial infarction** and **cardiomyopathy.**

THANK YOU