CARDIAC CYCLE

Definition. Changes that occur in the heart during one beat, are repeated in the same order in the next beat. This cyclical repetition of the various changes in heart, from beat to beat, is called **cardiac cycle.**

Cardiac cycle time. *This is the time required for one complete cardiac cycle.* With the normal heart rate of 75 per minute, this time will be 60/75= **0·8 sec.** It means that every event in the cycle will be repeated at the interval of 0·8 sec. It is obvious that the *cardiac cycle time will be inversely proportional to the heart rate.*

Interrelations of the various events in the cardiac cycle. In the cardiac cycle there are four main events: **atrial systole, atrial diastole, ventricular systole,** and **ventricular diastole.** All the other changes are subsidiary to them.

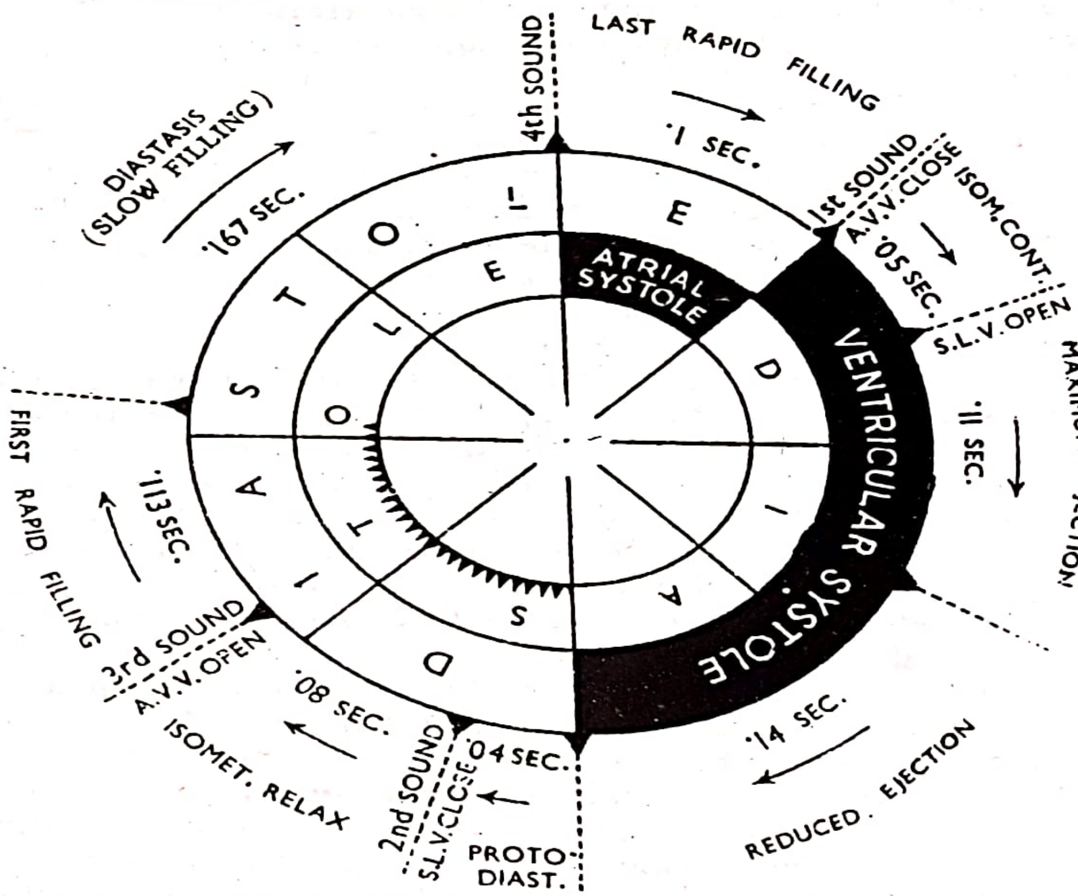

FIG. 171. Showing the sequence of events during cardiac cycle. Inner ring represents atrial events, outer ring ventricular events. The events are to be followed in clockwise manner.

Atrial systole initiates the cycle, because the pacemaker S. A. node is situated in it. It lasts for **0·1 sec.** and is followed by atrial diastole, lasting for **0·7 sec.** At the end of diastole, the atrial systole returns, and in this way, the atrial cycle goes on (total duration **0·8 sec.**).

At the end of atrial systole, ventricular systole starts—duration **0·3 sec.** This is immediately followed by ventricular diastole—duration **0·5 sec.** At the end of diastole, ventricular systole repeats and thus the ventricular cycle goes on (total duration **0·8 sec.**).

In order to follow the march of events during the cardiac cycle and their interrelations, the FIG. 171 should be carefully studied. In it, there are two concentric rings, divided into *eight* equal parts. The whole circle represents one complete cardiac cycle, so that each of its eight divisions represents 0·1 sec. The inner ring represents the atrial events, the outer ring ventricular events.

Let us follow the inner ring first. The *one* shaded division in it denotes atrial systole (0·1 sec.). During this period the atria contract and expel their contents into the respective ventricles. The left atrium, being further away from the S. A. node, contracts a little after the right atrium. But practically their contractions are simultaneous. The force of contraction is stronger in the first half than in the second. Because during first half or at initial stage the **intra-atrial pressure** remains high and during last half the same is decreased due to expulsion of blood to the ventricle (FIG. 172).

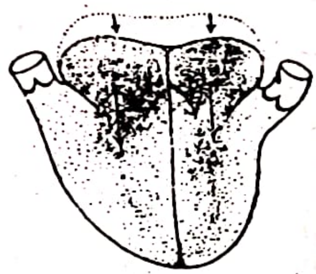

FIG. 172. Heart during atrial systole. Atria shorten, A.V.V.—open. S. L. V.—closed.

After atrial systole, comes its diastole (0·7 sec.), being represented by *seven* unshaded divisions in the ring. During this period the atria relax and receive blood from the great veins—the right atrium from the venae cavae, the left atrium from the pulmonary veins. At the end of this period, the atrial systole comes again and in this way, the atrial events go on.

Let us now follow the ventricular events in the outer ring. There are *three* shaded divisions on it, representing ventricular systole (0·3 sec.). It is followed by *five* unshaded divisions, indicating ventricular diastole (0·5 sec.). On comparing the two rings, it would be found that ventricular systole commences at the end of atrial systole. The reason for this is very clear. The impulse originating at the S. A. node, will certainly overtake the atrium first, then it will travel down the junctional tissues, enter the ventricles and stimulate their contraction. Naturally then, ventricular systole will always come after atrial systole.*

From these interrelations we can deduce one **fundamental rule** of cardiac action that—*the systoles of atrium and ventricle will never overlap*. In other words, when one chamber is contracting, the other must be relaxing.

At the onset of ventricular systole, the **first sound** occurs. It is caused by the sudden closure of the A. V. valves due to sharp rise of intraventricular pressure. The semilunar valves open a little later, because, until the intraventricular pressure goes above that in the aorta and pulmonary artery, the semilunar valves will not open. Thus, at the beginning of ventricular systole, there is a brief period during which both the valves are closed and the ventricles are contracting as closed cavities (FIG. 173). No blood passes out and therefore, no shortening of the cardiac muscle will occur. Hence, this period is called **isometric contraction period** (0·05 sec). It is marked at the onset by the closure of the A. V. valves (e.g., the first sound) and at the termination by the opening of the semilunar valves.

* The time relations are so adjusted that the atrioventricular conduction time of the impulse (P–R interval of *Electrocardiogram*) is a little longer (0·16 sec.) than the duration of atrial systole (0·1 sec.). This explains why ventricular systole must always come after atrial systole normally.

At the end of this period, the semilunar valves open and the **ejection period** starts, (0·25 sec.). During this period, blood is expelled from the ventricles—from the left ventricle into the systemic aorta, from the right into the pulmonary trunk. In the first part of this period (0·11 sec.) the outflow is very rapid. Hence, it is known as the **maximum ejection period** (FIG. 174). In the last part (0·14 sec.) the rate of outflow slows down. Hence, it is called the **reduced ejection period** (FIG. 175). Here, the ventricular systole ends and diastole begins.

Let us follow the outer ring further. It will be seen that after the three shaded divisions, come the *five* clear divisions—representing the duration of ventricular diastole (0·5 sec.). As soon as ventricles relax, the intraventricular pressure starts falling. The blood columns in the aorta and pulmonary trunk try to roll back towards ventricles but are stopped by the sharp closure of the semilunar valves. This produces the **second sound** of heart. Thus the onset of ventricular systole is marked by the first sound and its termination by the second sound (approximately).

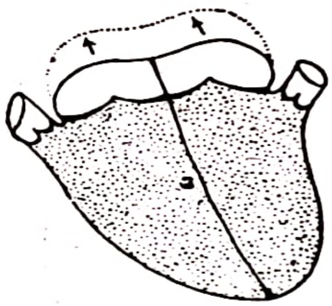

FIG. 173. Heart, during isometric contraction phase. Atria relaxing. Both valves closed. No shortening of ventricles.

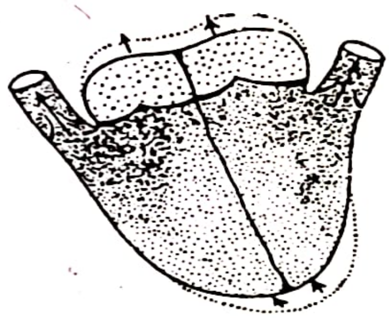

FIG. 174. Heart, during maximum ejection period. A. V. V.—closed. S. L. V.—open. Atria relaxing. Ventricles shortening.

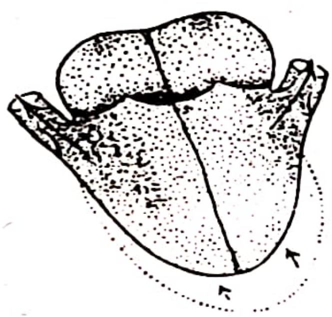

FIG. 175. Heart, during reduced ejection period. A.V.V.—closed. S. L. V.—open. Ventricles much shortening. Atria—full.

On comparing the two rings, it will be seen that the last one division (0·1 sec.) of ventricular diastole is overlapped by atrial systole. In other words, when atria are contracting, the ventricles are still in diastole and are having the last part of their filling. It will be seen further that the first four divisions of ventricular diastole coincide with the corresponding four divisions of the atrial diastole. From this we can come to another **fundamental rule** of cardiac action that—*the diastole of the two chambers will always partly overlap*. In the left half of the FIG. 171 unshaded division will be found. In other words, both the chambers are in diastole here. This is called the **diastole of the whole heart** (0·4 sec.).

Let us again follow the ventricular diastole on the outer ring. As mentioned above, the second sound occurs at the end of ventricular systole. But this statement is not exact, because, till the falling of intraventricular pressure goes below the intra-aortic pressure, the semilunar valves will not close. Consequently, there will be a short interval between the onset of diastole and the closure of the semilunar valves (i.e., the second sound). This period is called the **protodiastolic period** (0·04 sec.). From this it is clear that the second sound does not occur just at the end of ventricular systole but a little afterwards (i e., after the protodiastolic period).

Although the semilunar valves have closed, yet the A. V. valves are still not open. Because, the falling intraventricular pressure takes a little time to go below that of the atria, so that the A. V. valves may open. Consequently, there will be a brief interval during which both the valves remain closed and ventricles are relaxing as closed cavities. Since no blood enters the ventricles there will be no lengthening of cardiac muscle fibres. Owing to this, it is called the **isometric relaxation period** (0·08 sec.—FIG. 176).

At the end of isometric relaxation period, the A. V. valves open. Blood rushes into the ventricles and ventricular filling begins. The first part of this period is known as the **first rapid filling phase** (0·113 sec.). Because, as soon as the A. V. valves open, blood accumulating so long in the atria, rushes into the ventricles. The steep fall of the intraventricular pressure during the isometric relaxation period, makes the inflow all the more intense. Although the duration is brief yet the largest part of ventricular filling takes place during it. Due to rapid rush of blood a sound is produced, known as the **third sound** of heart (FIG. 177).

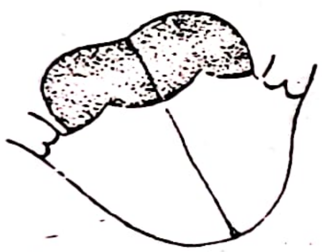

FIG. 176. Heart, during isometric relaxation period. Both valves closed. Ventricles relaxing. No blood entering, hence no lengthening of ventricles.

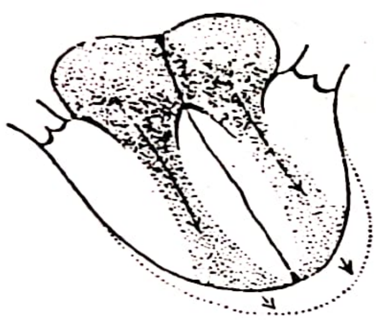

FIG. 177. Heart, during first rapid filling phase. A.V.V.—open. Blood rushing into the ventricles. Ventricles relaxing and lengthening. S.L.V.—closed.

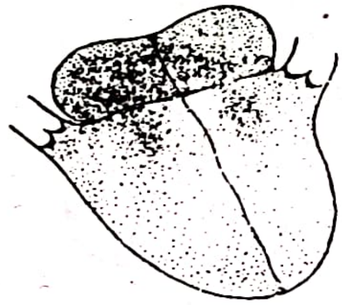

FIG. 178. Heart, during diastasis. A.V.V.—Floating in neutral position. S.L.V.—closed. Both atria and ventricles filled up.

In the next phase of diastole, the rate of filling slows down. The ventricles are already full to a large extent and ventricular pressure slowly rises. Consequently, the rate of inflow from the atria will be gradually slower. This period is called **diastasis** or **slow inflow phase** (0·167 sec.). Although this is the longest phase of ventricular diastole, yet the amount of filling during this period is minimum. If one looks into the heart (FIG. 178) during this time, one will find that, the whole atrioventricular canal contains a continuous column of blood, more or less stagnant, in which the cusps of the A. V. valves are passively floating. After this period comes the last part of ventricular diastole represented by the last unshaded division on the outer ring. It is obvious that this phase corresponds with atrial systole. Due to atrial contraction, blood rushes into the ventricles and ventricular filling again becomes rapid. This phase—the last rapid filling phase—the **last rapid filling phase** (0·1 sec.) is responsible for the last part of ventricular filling. Due to rapid rush of blood, again a sound is produced—known as the **fourth sound** of heart. Thus the onset of filling period is marked by the third sound and its termination by the fourth sound. Here the ventricular diastole ends. They are completely filled up, the impulse from the S. A. node arrives in the mean time and the ventricles plunge into systole again. Thus the cycle goes on.

Summary of the sequence of events in cardiac cycle. The **atrial systole** is the first event (0·1 sec.). It initiates the cardiac cycle, because the pacemaker S. A. node is situated here. Due to higher atrial pressure, the first half of atrial systole is stronger than that of the last half. After systole comes the **atrial diastole** (0·7 sec.). These two alternately follow each other and constitute the atrial cycle (0·8 sec.).

Just after the atrial systole, the **ventricular systole** (0·3 sec.) begins and is immediately followed by its diastole (0·5 sec.). These two events repeat alternately and make up the ventricular cycle (0·8 sec.).

At the onset of ventricular systole, the A. V. valves close producing the **first sound.** The semilunar valves open a little later. The interval between the closing of the A. V. valves and opening of the semilunar valves, is called the **isometric contraction period** (0·05 sec.). During this period ventricles contract as closed cavities and intraventricular pressure steeply rises.

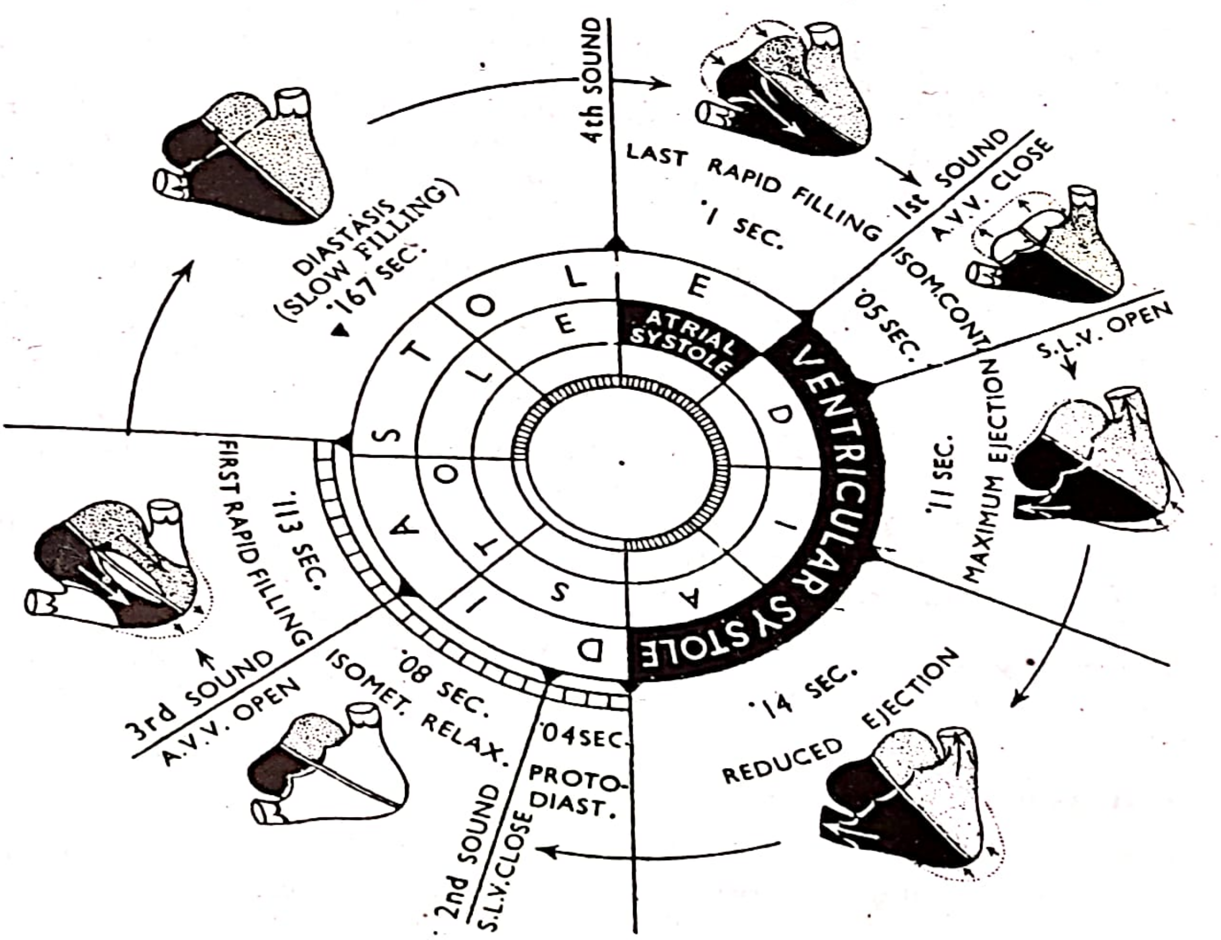

FIG. 179. Represents the interrelations of the important events of the cardiac cycle. Condition of heart corresponding to each important phase is also shown.

After this phase, comes the **ejection period**—when blood is pumped out of the ventricles. The first part of this period, when the outflow is very rapid, is called the **maximum ejection period** (0·11 sec.). The second part, when the rate of flow slows down, is known as the **reduced ejection period** (0·14 sec.). Here, ventricular systole ends and diastole begins.

At the beginning of ventricular diastole, the semilunar valves close producing the **second sound.** There is a brief interval between the beginning of diastole and the closure of the semilunar valves—known as the **protodiastolic period** (0·04 sec.). So that, second sound occurs actually after this period. The A. V. valves open a little after the closing of the semilunar valves. The interval between these two is called the **isometric relaxation period** (0·08 sec.). During this period ventricles relax as closed cavities and intraventricular pressure steeply falls. At the end of this period, the intraventricular pressure goes below that of the atria and the A. V. valves open. Atrial blood rushes into the ventricles—producing the **third sound.** Here, ventricular filling begins. The first part of filling is very rapid, being known as the **first rapid filling phase** (0·113 sec.). The maximum filling takes place during this brief period. The intermediate part of filling is very slow and is known as **diastasis** or **slow inflow phase.** Although this is the longest phase (0·167 sec.), yet the amount of filling is minimum. The last part of diastole corresponds with atrial systole. Due to active contraction of the atria, filling becomes very rapid. This **last rapid filling phase** (0·1 sec.) is responsible for the last part of ventricular filling. Due to rapid rush of blood, another sound is produced—the so-called **fourth sound** of heart. Here, ventricular diastole ends and systole commences again. In this way the cycle continues (Fig. 179).

TIME RELATIONS OF THE VARIOUS EVENTS

It has been noted that the cardiac cycle time is inversely proportional to heart rate. But all the phases of cardiac cycle do not proportionally vary. *The duration of diastole varies much more than that of systole.* For instance, with a rate of 120 per minute the cardiac cycle time will be 0·5 sec. The systolic period will be reduced to 0·23 sec. and diastolic period to 0·27 sec. With a rate of 60 per minute the cycle time is 1 sec. Here, the systole will be 0·33 sec. and diastole 0·67 sec. Thus when the rate rises from 60 to 120 per minute the systole diminishes only by 0·1 sec., whereas diastole diminishes by 0·4 sec. *In other words, heart rate varies more at the expense of diastole than that of systole.*

Summary of the time relations. With 0·8 sec. as the cardiac cycle time (heart rate 75 per minute), the time relations of the various events are given below:

I. Atrial events:

(*a*) Atrial Systole		0·1 sec.
1. First Phase (at rise of pressure)	0·05 sec.	
2. Second Phase (at fall of pressure) ..	0·05 sec.	
(*b*) Atrial Diastole		0·7 sec.
	Total	0·8 sec.