The Cardiac Cycle

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Lecture Objectives:

1. Define cardiac cycle.
2. Be familiar with and explain curves for the various events occurring in the heart, inlet veins, and outlet arteries.
3. Recognize systolic and diastolic duration.
4. Understand isometric and relaxation; and the ejection phases.
5. Explain volume – pressure relationship in the left ventricle.
6. Explain the development of first and second heart sounds.
7. Define murmurs and how systolic and diastolic murmurs are produced.

- **Definition:**

  The cardiac events that occur from the beginning of one heart beat to the beginning of the next

- **The Cardiac Cycle consists of *Diastole and Systole***

  During diastole → heart relaxes and fills with blood

  During systole → the heart contracts and eject blood (i.e. emptying)

Note: If heart rate is 72 beats/min, the duration of the cardiac cycle is about 0.8 second per beat. Of which 0.3 second is for systole and 0.5 second is for diastole.

Atrial contraction (= Primer Pump)

Normally 80% of the ventricular filling is achieved even before the onset of atrial contract.

Atrial contraction usually increases the ventricular pumping effectiveness as much as 20%. However; atrial failure is only noticed in exercise, then signs of heart failure develop, especially dyspnea (shortness of breath)

Systole is composed of:

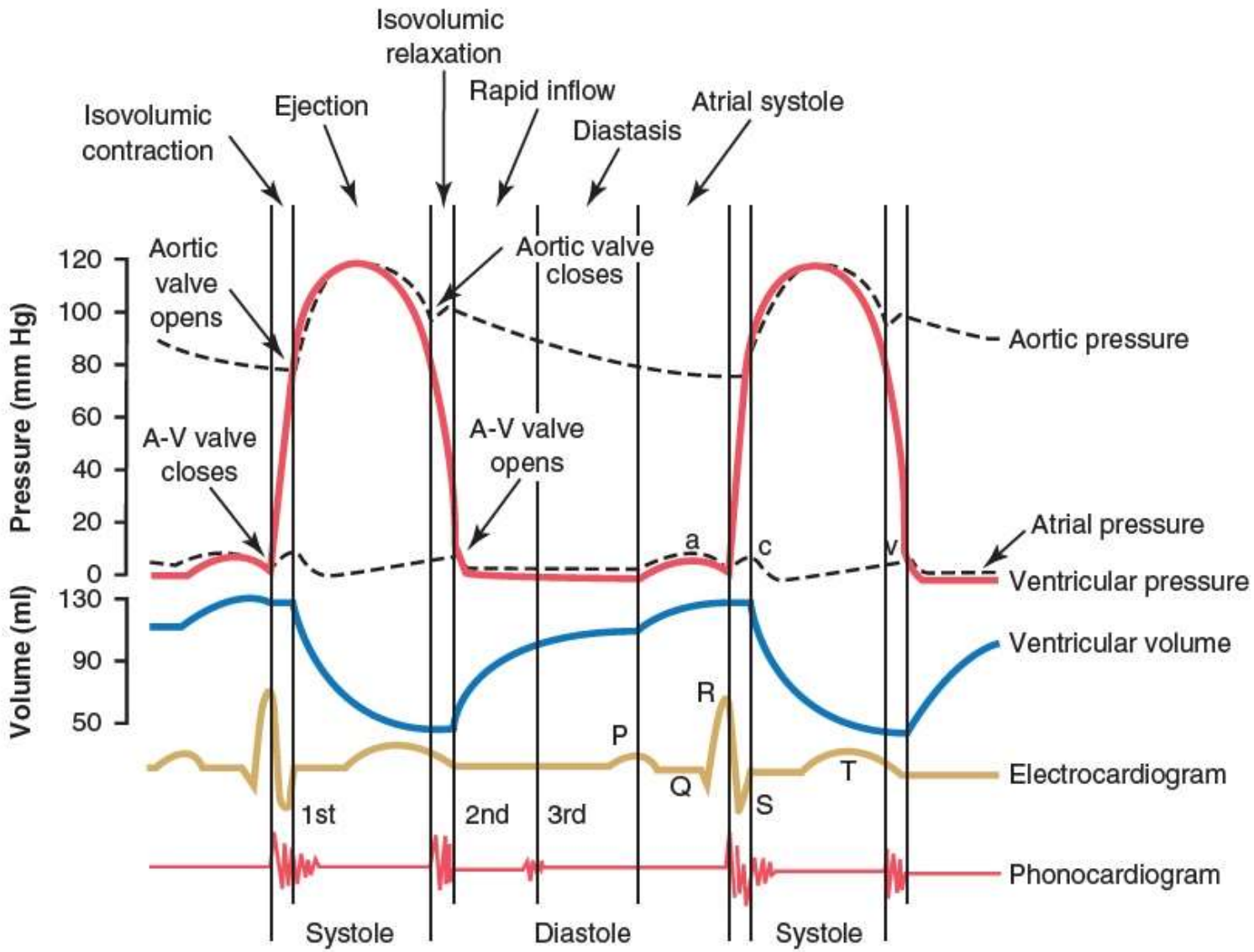
1. Isovolumic (isovolumetric) contraction phase. In this phase cardiac muscle tension is increasing but little or no shortening of the muscle fibers is occurring.
2. Ejection phase (70% of ejection is completed in the first ⅓ of the phase).

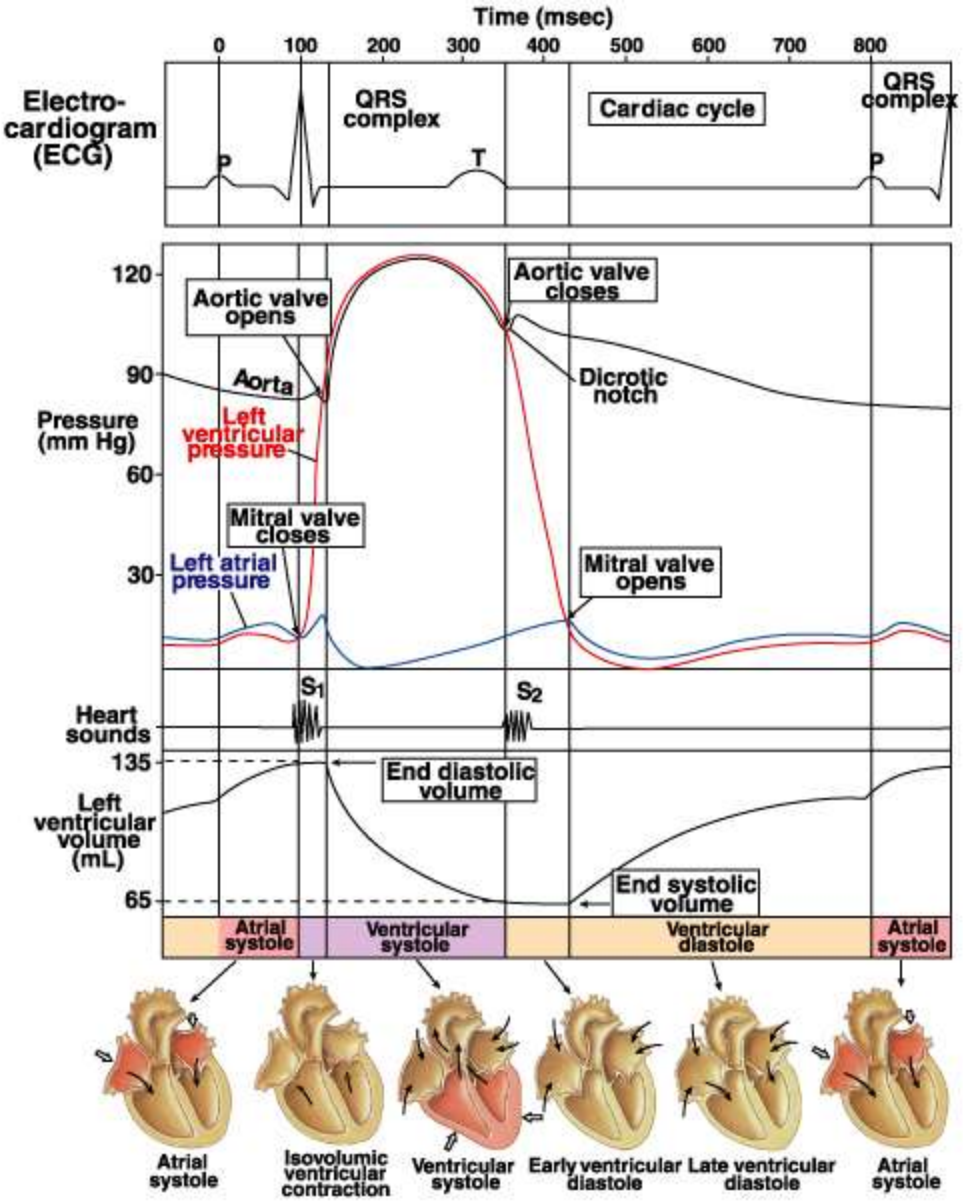
Diastole is composed of:

1. Isovolumic (isovolumetric) relaxation phase
2. Ventricular filling phase – this phase can be further divided into three thirds, namely the rapid filling, reduced filling (diastases), and the contribution of atrial contraction

The Cardiac Volumes

- End diastolic volume (110-120 ml) – it is the maximal amount of blood the ventricle contains during the cycle. The maximal value it can reach is 150-180 ml. The EDV is an index of the ***Preload***
- End systolic volume (40-50 ml) – it is the least amount of blood the ventricle contains during the cycle. The minimal value it can reach is 10-20 ml. The higher the myocardial contractility the lower is the ESV.
- Stroke volume output (70 ml) – it is the amount of blood pumped out of each ventricle with each contraction. SV= EDV – ESV
- The ejection fraction (EF) is the fraction of the EDV that is ejected. It is usually equal to about 60 percent.


Isovolumic relaxation
Isovolumic contraction
Ejection
Rapid inflow
Diastasis
Atrial systole
Aortic valve opens
Aortic valve closes
A-V valve closes
A-V valve opens
Pressure (mm Hg)
120
100
80
60
40
20
0
Aortic pressure
Atrial pressure
Ventricular pressure
a
c
v
Volume (ml)
130
90
50
Ventricular volume
R
P
Q
S
T
Electrocardiogram
1st
2nd
3rd
Phonocardiogram
Systole
Diastole
Systole


Time (msec)
0
100
200
300
400
500
600
700
800
Electro-cardiogram (ECG)
P
QRS complex
T
Cardiac cycle
P
QRS complex
120
90
60
30
Pressure (mm Hg)
Aortic valve opens
Aorta
Left ventricular pressure
Aortic valve closes
Dicrotic notch
Mitral valve closes
Left atrial pressure
Mitral valve opens
S1
S2
Heart sounds
135
65
Left ventricular volume (mL)
End diastolic volume
End systolic volume
Atrial systole
Ventricular systole
Ventricular diastole
Atrial systole
Atrial systole
Isovolumic ventricular contraction
Ventricular systole
Early ventricular diastole
Late ventricular diastole
Atrial systole

Atrial Pressure Changes and the Jugular Pulse

When the right atrium contracts, a retrograde pressure pulse wave is sent backward into the jugular vein producing three characteristic waves in the record of jugular pressure.

- The **a wave** is due to atrial systole.

  Factors that impede the flow of blood from the atria to the ventricles, such as *tricuspid valve stenosis*, increase the amplitude of the a-wave.
- The **c wave** is produced by the bulging of the tricuspid valve into the atria during isovolumetric ventricular contraction.

  Tricuspid valve incompetence results in a high amplitude c-wave.
- The **v wave** mirrors the rise in atrial pressure before the tricuspid valve opens during diastole.

  Tricuspid valve stenosis results in an attenuation of the descending phase of the v-wave.

The Heart Sounds

1. The First Heart Sound (S_1) (lub) is associated with the closure of the atrioventricular valves. It signifies the start of systole. It is a low-pitched sound.

   The intensity of the first heart sound is proportional to the strength of myocardial contraction, and its evaluation is useful in clinical diagnosis.

2. The Second Heart Sound (S_2) (dub) is caused by the sudden closure of the semilunar valves. Its intensity is proportional to the intensity of the valve closure.

   Clinically, it signifies the end of systole and the start of diastole. However, systole is more correctly considered to be concluded when the T wave ends on the ECG.

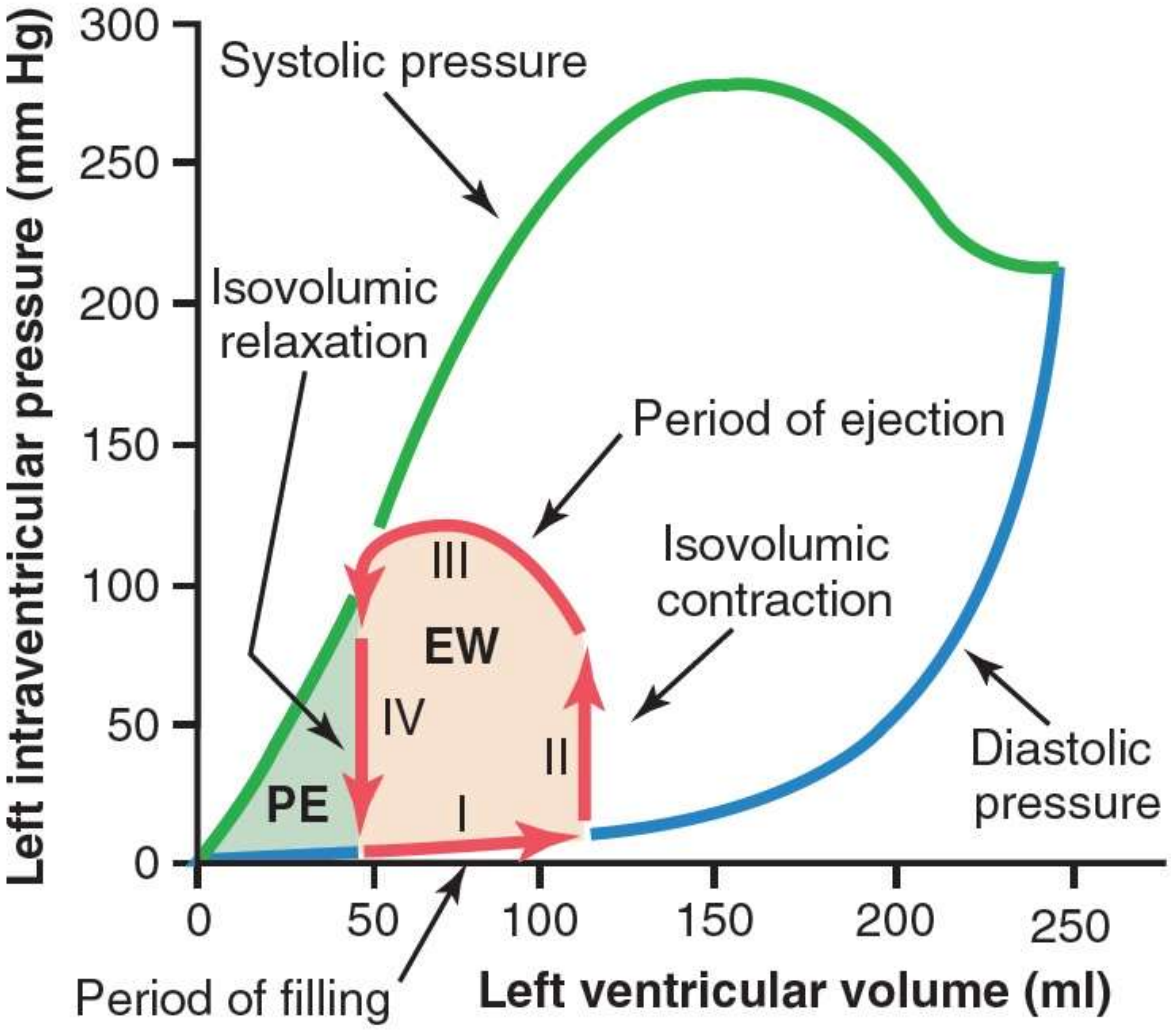
   Splitting of S_2, also known as **physiological split**, normally occurs during deep inhalation. A widely split S2 can be associated with several different cardiovascular conditions, including Right bundle branch block and atrial septal defect.

3. The Third Heart Sound is not normally heard in healthy people. This sound is due to abrupt cessation of ventricular distention and the deceleration of blood flow just before diastasis.

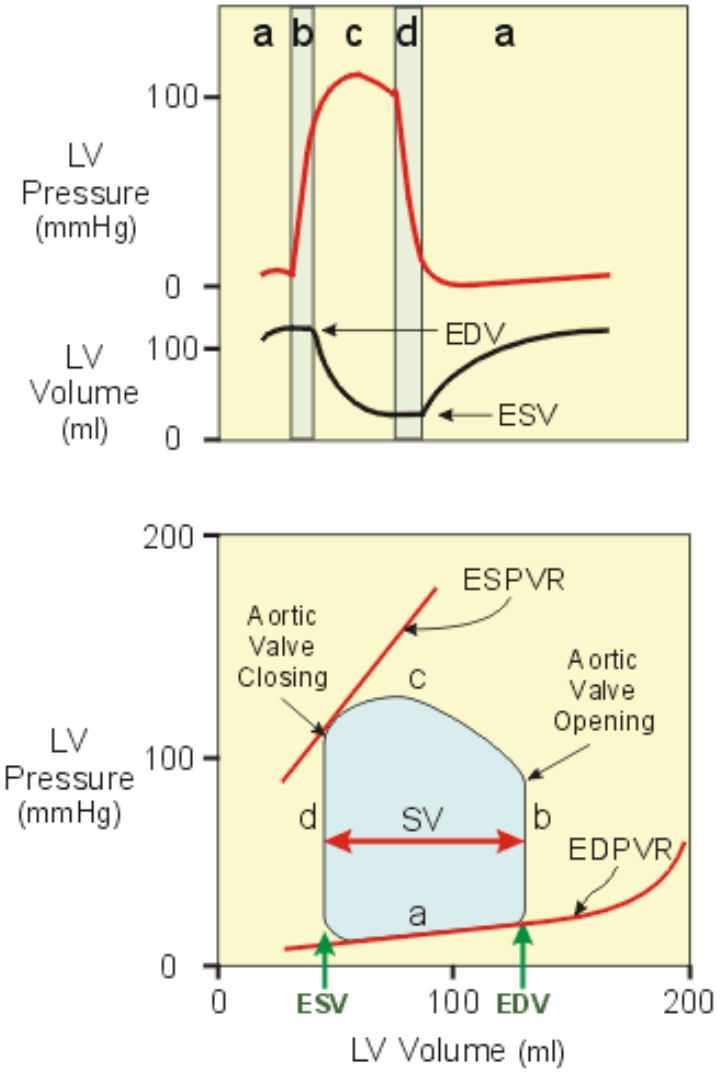
   The third heart sound is amplified in abnormally stiff or distended ventricles, such as that associated with **heart failure**, and its presence over the age of 40 is considered a serious sign of underlying cardiac abnormalities.

The Volume-Pressure Curves

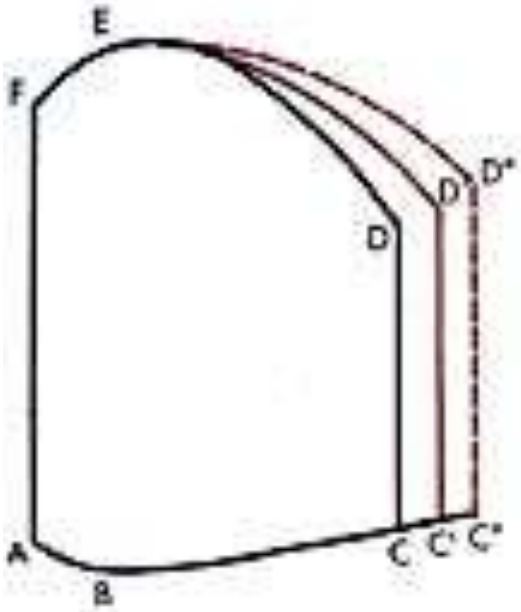
1. The diastolic pressure curve – notice the significant rise in pressure after 150 ml filling.
2. The systolic pressure curve – notice that maximum pressure is reached at 150-170 ml filling then pressure decline starts.
3. The Volume – Pressure loop – it describes the cycle independent of time factor.



Relationship between left ventricular volume and intra-ventricular pressure during diastole and systole. Also shown by the red lines is the "volume-pressure diagram," demonstrating changes in intra-ventricular volume and pressure during the normal cardiac cycle. EW, net external work; PE, potential energy.



The generation of a left ventricular pressure-volume loop *(bottom panel)* from pressure and volume changes during cardiac cycle *(top panel)*. *Abbreviations:* a, ventricular filling; b, isovolumetric contraction; c, ventricular ejection; d, isovolumetric relaxation; EDV and ESV, left ventricular end-diastolic and end-systolic volumes, respectively; EDPVR, end-diastolic pressure-volume relationship; ESPVR, end-systolic pressure-volume relationship.



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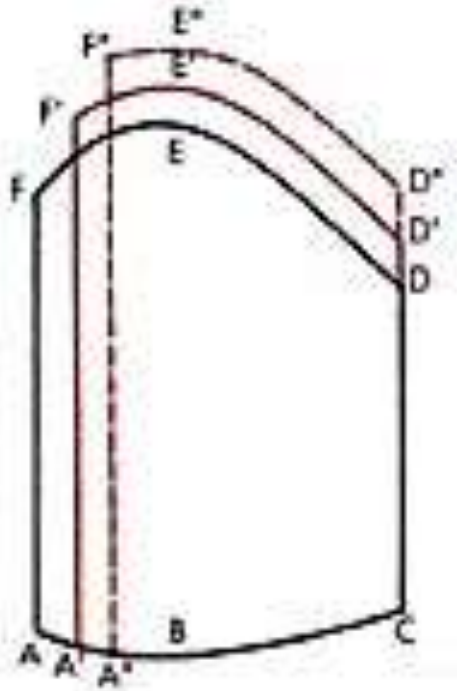

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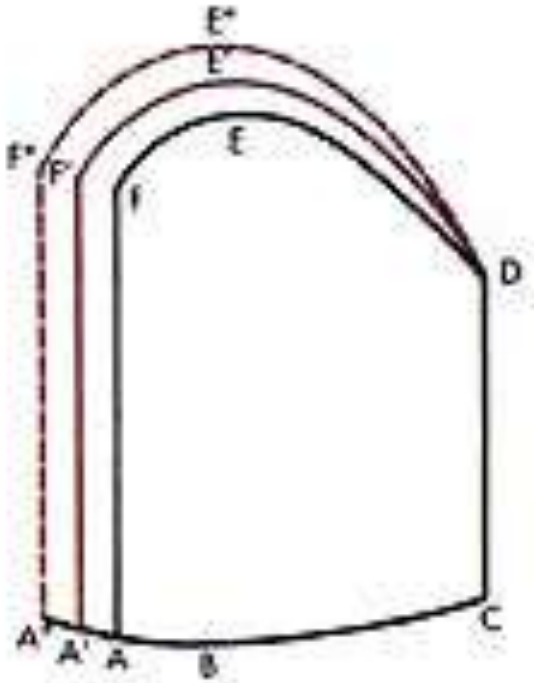

Increased contractility

Test Question:

Q. The dicrotic notch on the aortic pressure curve is caused by?

A. Closure of the mitral valve.

B. Closure of the tricuspid valve.

C. Closure of the aortic valve.

D. Closure of the pulmonary valve.

E. Rapid filling of the left ventricle.