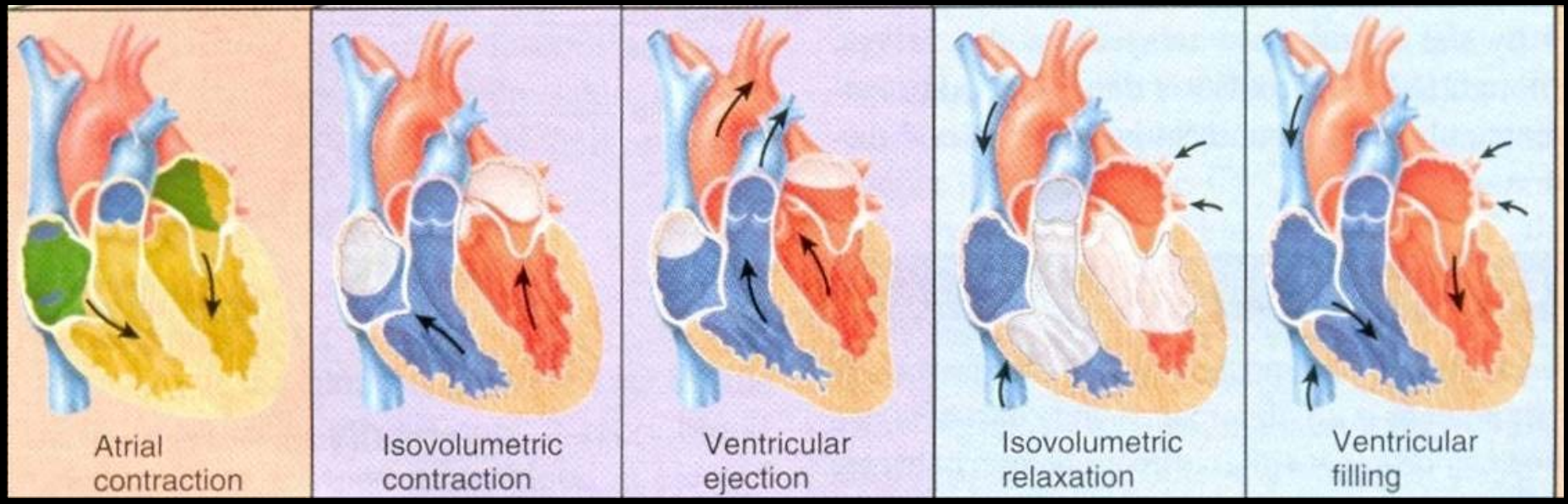
CARDIO-VASCULAR SYSTEM

- Dr. Chetna Ramanuj



Cardiac cycle

Cardiac cycle is the term referring to all or any of the events related to the flow or blood pressure that occurs from the beginning of one heartbeat to the beginning of the next.

- It consists of all of the mechanical, electrical, and valvular events taking place in the heart during a single contraction.

Cardiac cycle

There are two phases of cardiac cycle

Atrial events:

Atrial Systole : 0.1 sec

Atrial Diastole : 0.7 sec

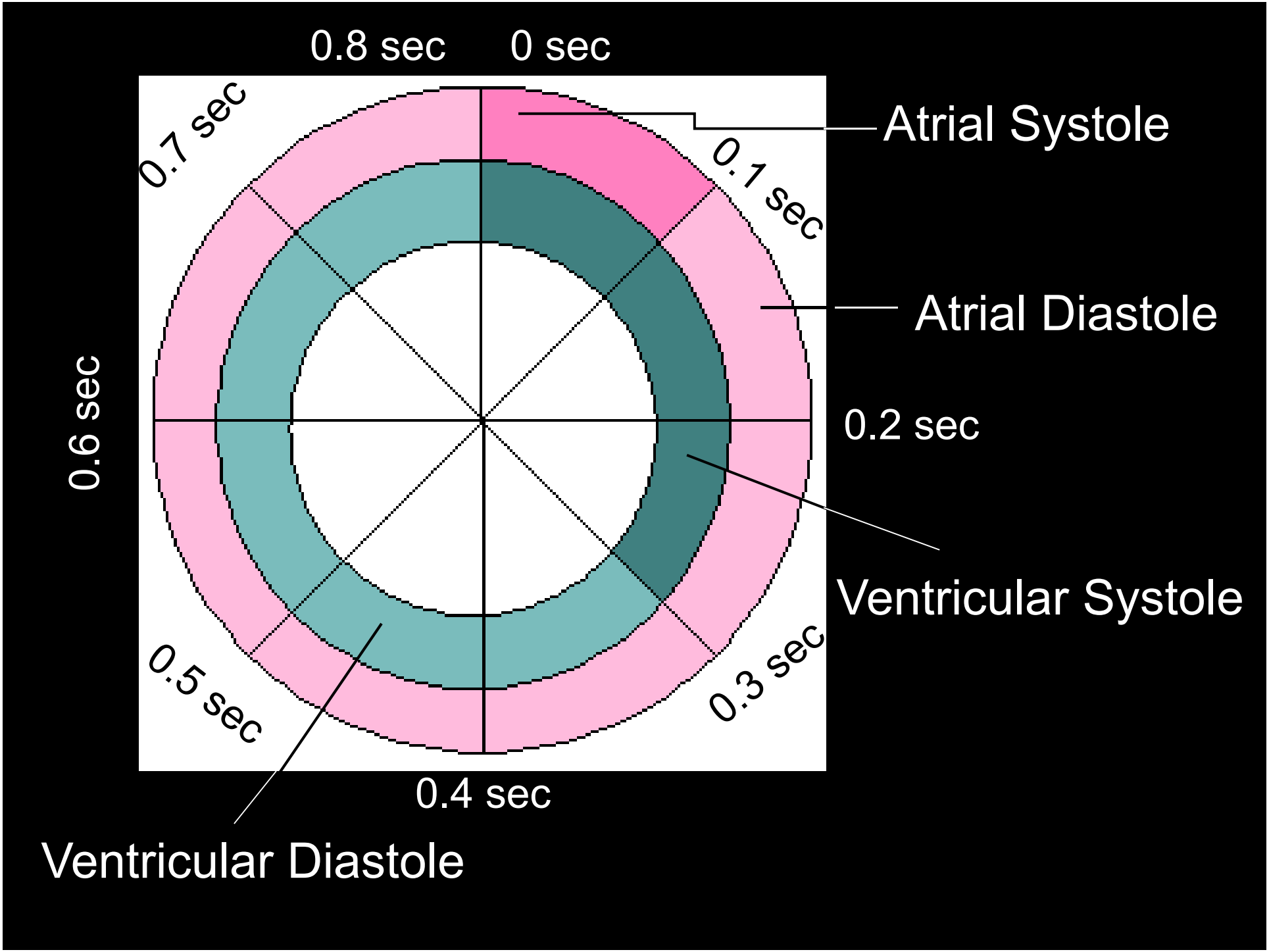
Ventricular events:

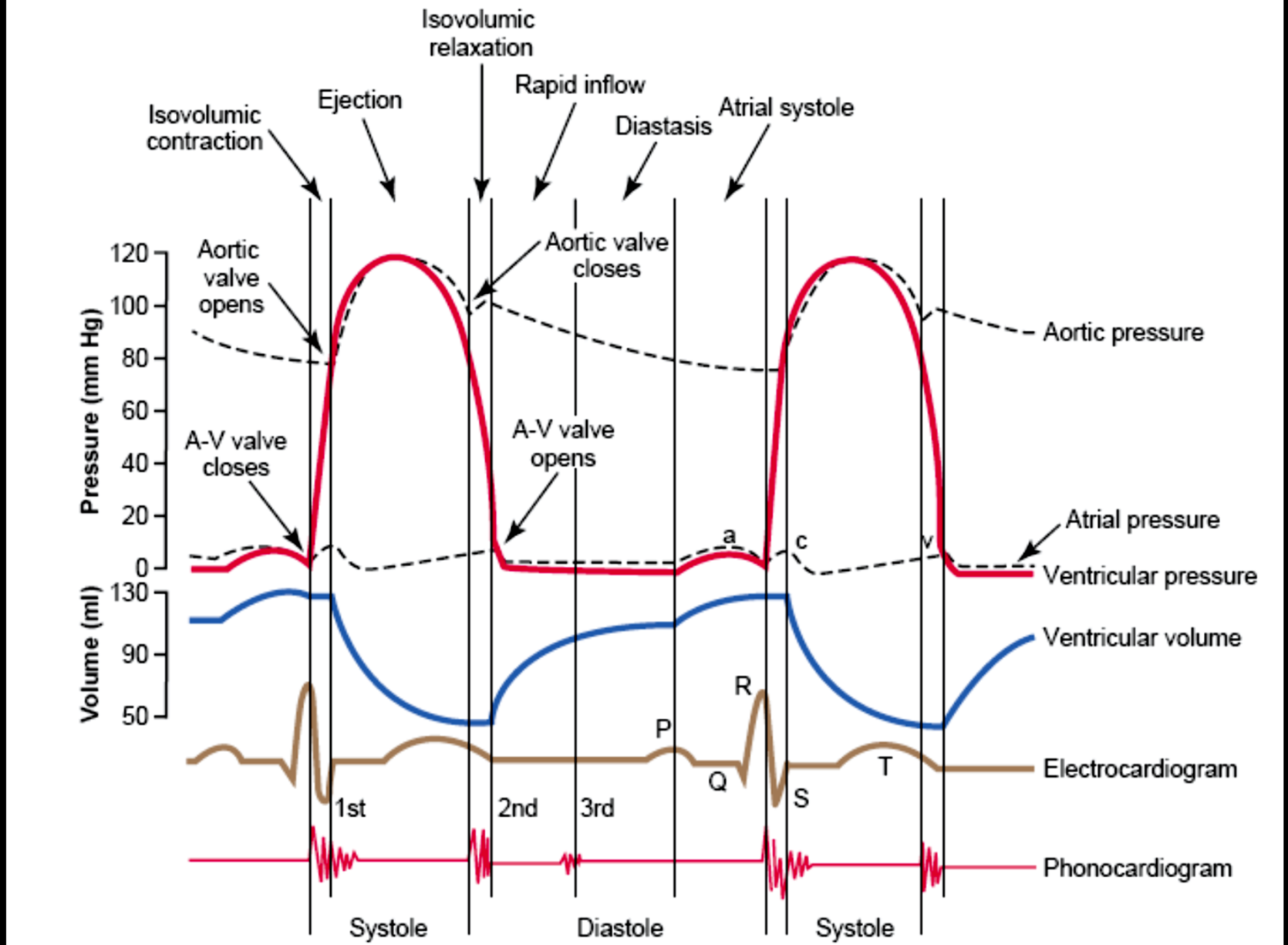
Ventricular Systole : 0.3 sec

Ventricular Diastole : 0.5 sec

Ventricular events can be further divided into:

systole- (.3 sec) -	isometric contraction	.05
	rapid ejection phase	.11
	slow ejection phase	.14
diastole-(.5 sec)-	Isometric relaxation	.1
	1st rapid filling	.1
	slow filling/ diastasis	.2
A systole	last rapid filling	.1


0.8 sec
0 sec
0.7 sec
0.1 sec
Atrial Systole
Atrial Diastole
0.6 sec
0.2 sec
Ventricular Systole
0.5 sec
0.3 sec
0.4 sec
Ventricular Diastole


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

Every step to be described on-

1) Closure & opening of valves with H sound

2) Blood moving from _ to _

3) Volume changes & volume curve

4) Pressure changes & pressure curve

5) Relation of ECG changes

Atrial pressure / jugular venous curve

a wave- atrial systole

c wave- bulging on AV into atria

v wave- filling of atria with closed AV valves

Pressure changes (mmHG) during systole & diastole in cardiac cycle

Rt atrium-5-6/0	Lt atrium-7-8/0
t	m
Rt ventricle- 25/0	Lt ventricle- 120/0
p	a
Pulmonary Trunk- 25/8	Aorta- 120/80

Pressure changes in atria during cardiac cycle.

1. **'a' wave**

   is caused by increase atrial pressure due to atrial contraction. wave appears during atrial systole.

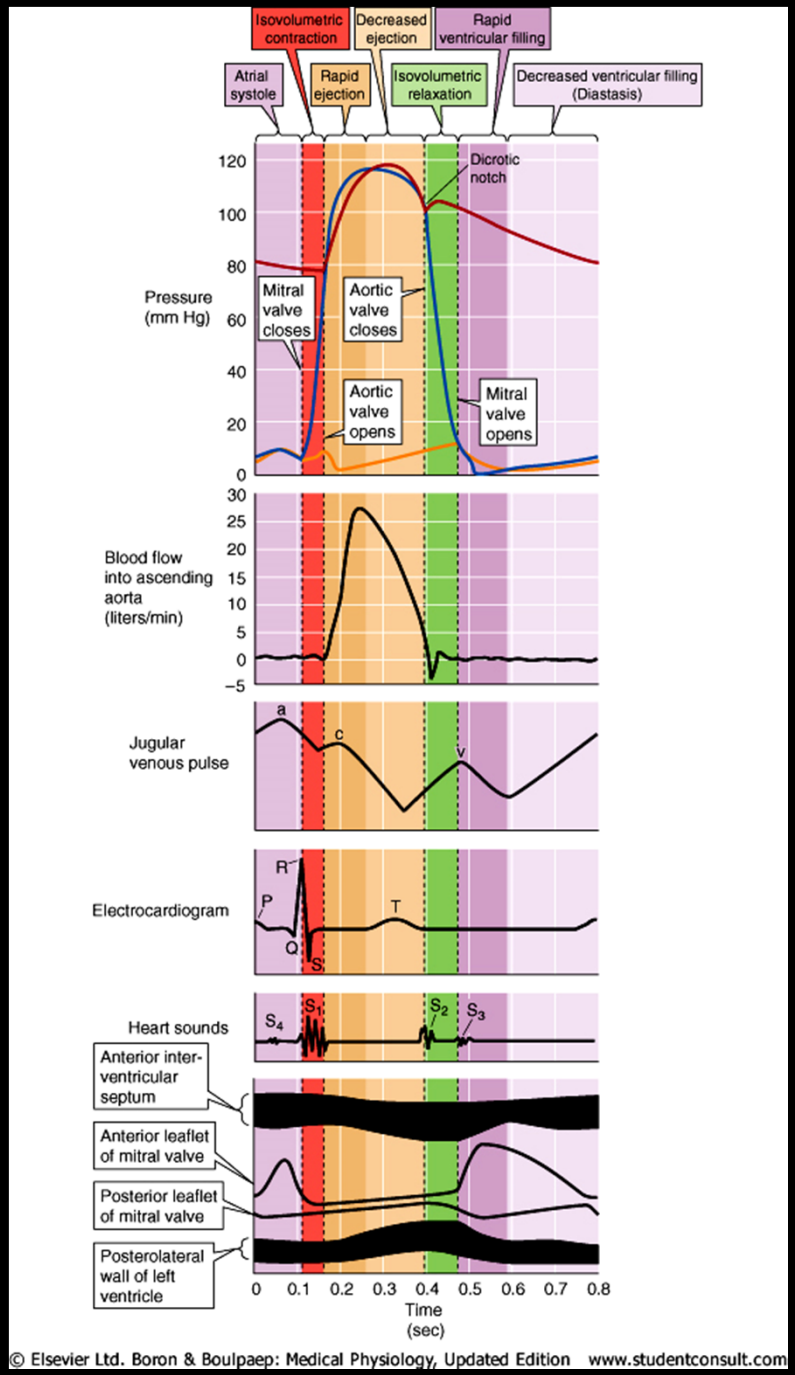
2. **'c' wave**

   is caused due to bulging of AV valves towards the atria because of increasing pressure in the ventricles. This wave appears in the phase of isovolumic contraction during ventricular systole

Pressure changes in atria during cardiac cycle.

3. V wave

results from slow build up of pressure in atria due to collection of blood from veins while AV valves are closed during ventricular contraction. This wave occurs therefore during isometric relaxation phase of ventricle.


Isovolumetric contraction
Decreased ejection
Rapid ventricular filling
Atrial systole
Rapid ejection
Isovolumetric relaxation
Decreased ventricular filling (Diastasis)
Pressure (mm Hg)
Dicrotic notch
Mitral valve closes
Aortic valve closes
Aortic valve opens
Mitral valve opens
Blood flow into ascending aorta (liters/min)
Jugular venous pulse
Electrocardiogram
Heart sounds
Anterior inter-ventricular septum
Anterior leaflet of mitral valve
Posterior leaflet of mitral valve
Posterolateral wall of left ventricle
Time (sec)
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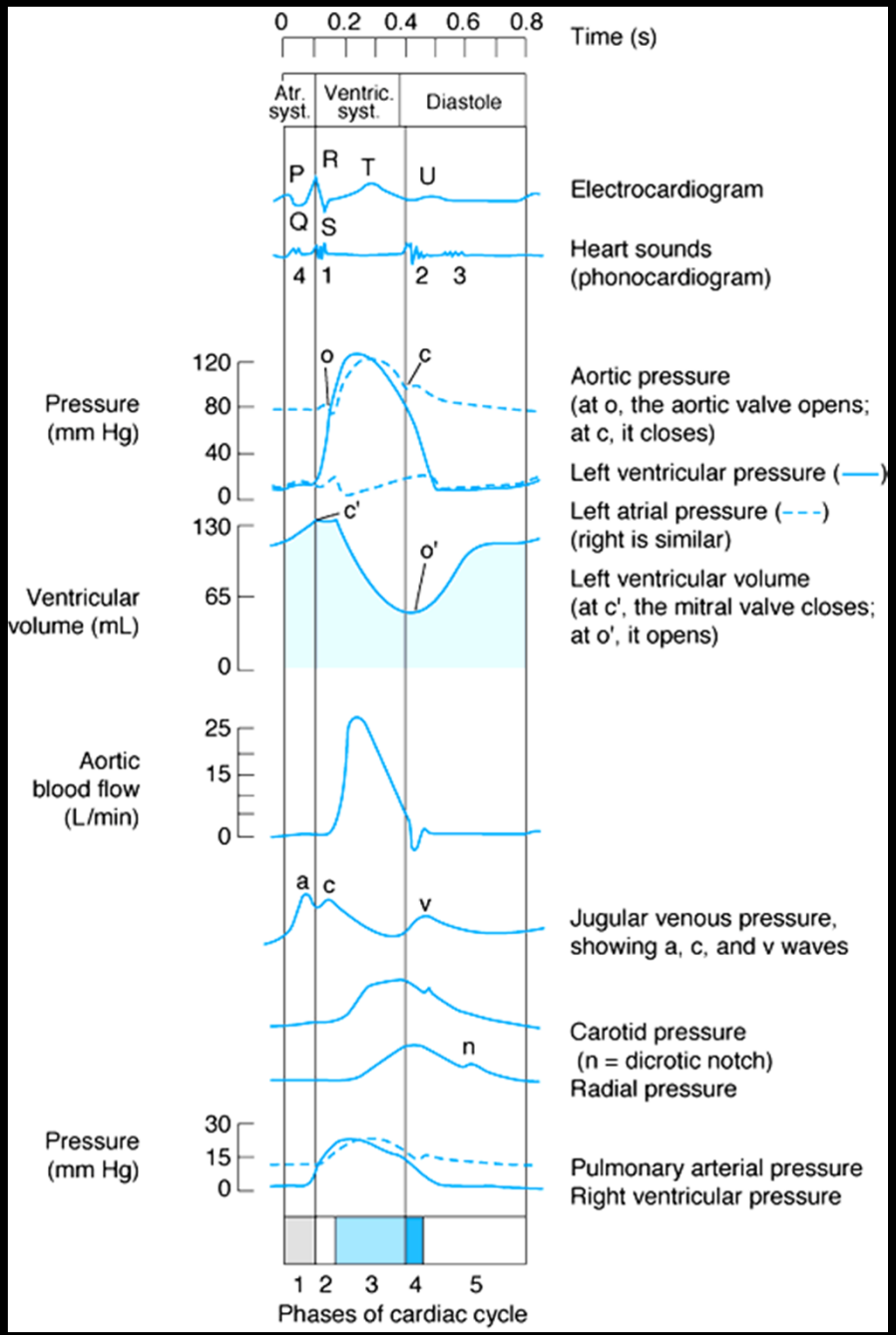
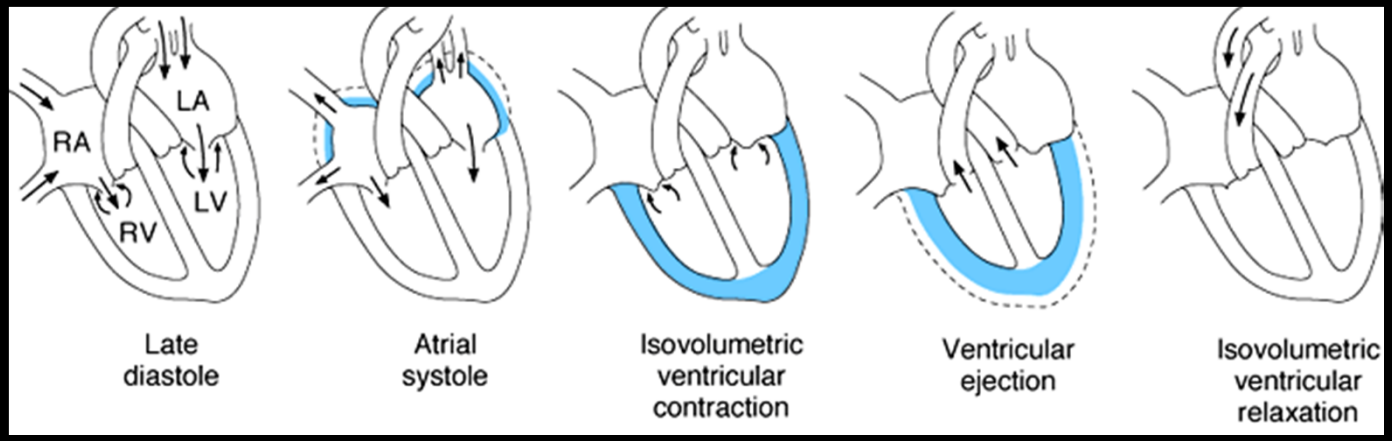
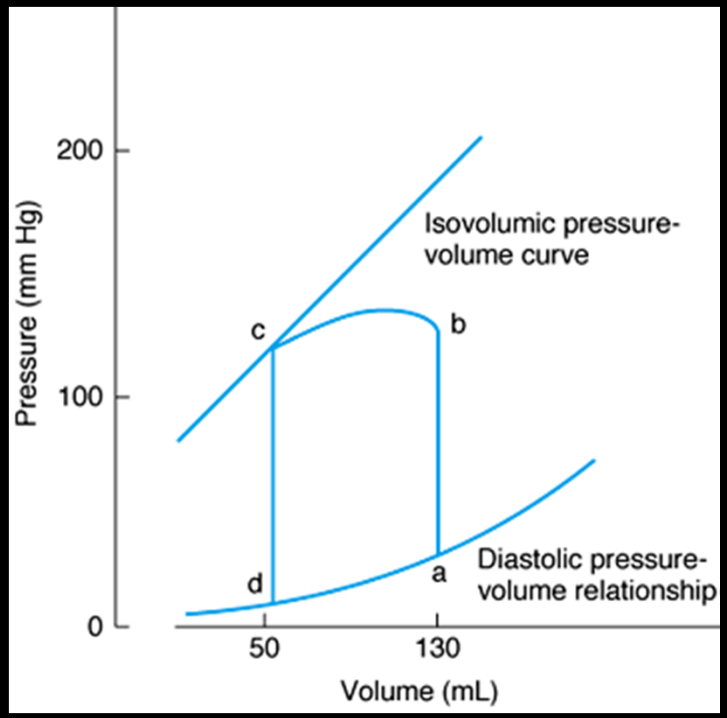

Time (s)
Atr. syst.
Ventric. syst.
Diastole
Electrocardiogram
Heart sounds (phonocardiogram)
Pressure (mm Hg)
Aortic pressure (at o, the aortic valve opens; at c, it closes)
Left ventricular pressure (——)
Left atrial pressure (- - -) (right is similar)
Ventricular volume (mL)
Left ventricular volume (at c', the mitral valve closes; at o', it opens)
Aortic blood flow (L/min)
Jugular venous pressure, showing a, c, and v waves
Carotid pressure (n = dicrotic notch)
Radial pressure
Pressure (mm Hg)
Pulmonary arterial pressure
Right ventricular pressure
Phases of cardiac cycle


RA
LA
RV
LV
Late diastole
Atrial systole
Isovolumetric ventricular contraction
Ventricular ejection
Isovolumetric ventricular relaxation


Pressure (mm Hg)
200
100
0
Isovolumic pressure-volume curve
c
b
d
a
Diastolic pressure-volume relationship
50
130
Volume (mL)

Isometric contraction(.05 secs)

At the beginning of this phase AV valves are closed but semilunar valves are not yet opened. Thus ventricular chambers are sealed from both atria and the arteries. The ventricle starts contracting but volume of blood inside both the ventricles remains the same hence this phase is called as isovolumic phase of contraction.

During this phase ventricles contract as a closed chamber and pressure inside the ventricles rises rapidly to a high value. When pressure in the left ventricle is slightly above 80 mm Hg and right ventricular pressure slightly above 8 mm Hg, then the ventricular pressures push the semilunar valves open. This causes ejection of blood from ventricles to the respective arteries in next phases.

Rapid ejection phase(.11 sec)

As soon as the semilunar valves open, blood is rapidly ejected. About two-third of the stroke volume is ejected in this rapid ejection phase. Pressure inside the left ventricle rises to 120 mm Hg during this phase. The end of rapid ejection phase occurs at about the peak of ventricular and atrial systolic pressure. The right ventricular ejection begins before that of left and continues even after left ventricular ejection is complete. As both the ventricles almost eject same volume of blood, the velocity of right ventricular ejection is less than that of the left ventricle.

Reduced ejection phase(.14 sec)

During later two-third of systole rate of ejection declines. During this phase of reduced ejection, rest onethird stroke volume is ejected.

During the period of slow ejection ventricular pressure falls to a value slightly lower than that in aorta but still blood continues to empty into aorta because blood flowing out has built up momentum. As this momentum decreases, kinetic energy of momentum is converted to pressure in the aorta. This causes aortic pressure to rise slightly above that of the ventricle.

Protodiastole-

At the end of ventricular systole, ventricles start relaxing allowing rapid fall in the intraventricular pressures. At the end of this phase, elevated pressures in distended arteries (aorta and pulmonary artery) immediately pushes the blood back towards the ventricles which snaps the aortic and pulmonary semilunar valves closed. This is the major component in generating second sound. It also causes dicrotic notch in the down slope of aortic pressure called incisura. Incisura indicates end of systole and the onset of diastole.

Isometric relaxation(.06 sec)-

The ventricles continue to relax as closed chambers as semilunar valves are closed and AV valves are not yet open. This causes rapid fall of pressure inside the ventricles (from 80 mm Hg to about 2 to 3 mm Hg in the left ventricle). Because the ventricular volume remains constant, this phase is called as isovolumic phase. When ventricular pressures fall below the atrial pressures the AV valves open.

Rapid filling phase(.1 sec)-

During ventricular systole because AV valves are closed, large amount of blood accumulates in atria because veins continue to empty the blood into them and this causes increase in pressure inside atria. High atrial pressure causes the blood to flow rapidly into the ventricles. Then pressures in both the chambers fall as ventricular relaxation continues.

Reduced filling phase or diastasis-

After the rapid filling phase, pressures in atria and ventricles rise slowly as blood continues to return to the heart. This decreases the rate of blood flow from atria to ventricles causing slow filling of ventricles called diastasis.

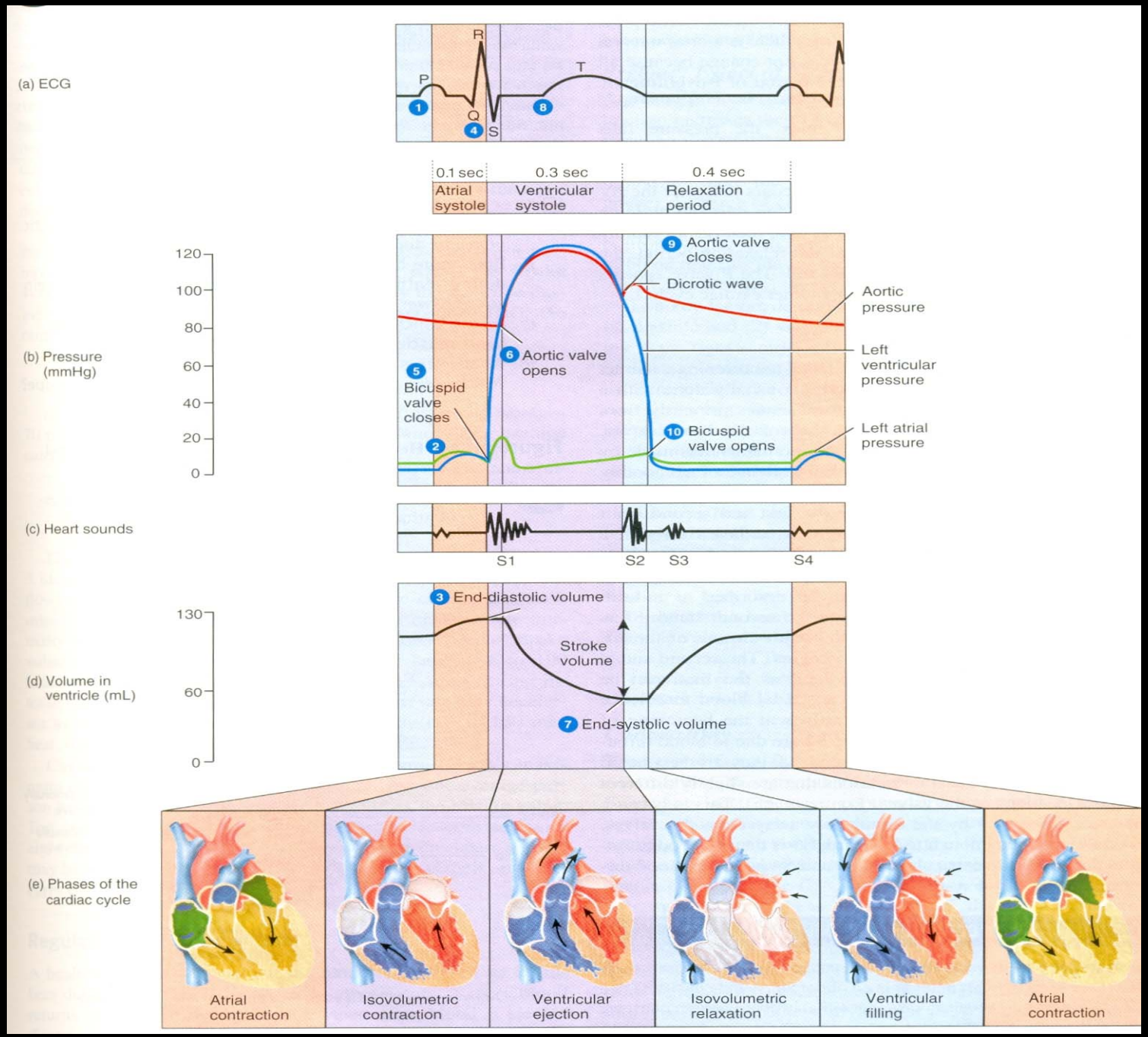
During rapid filling and diastasis phase about 75% of blood passes from atria to ventricles. Then the next cycle begins with atrial contraction.

Atrial systole (contraction).

During the period of ventricular relaxation, blood flows from atria to ventricles. About 75% of the blood flows to ventricles before atria contract. Both atria contract almost simultaneously and pump the remaining 25% of blood into the respective ventricles (therefore even if atria fail to function it is unlikely to be noticed unless a person exercises).

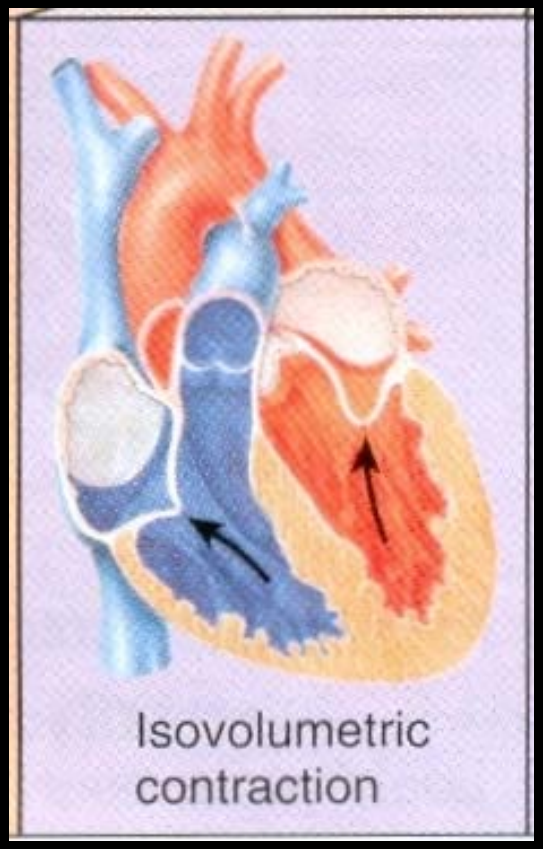
The contraction of atria increases, the pressure inside the atria to 4 to 6 mm Hg in the right atrium and about 7 to 8 mm Hg in the left atrium. The pressure rise in right atrium is reflected into the veins and this wave is recorded as ’a’ wave (recorded from jugular vein with the help of a transducer).

Then there is a period of atrial diastole for rest of the cardiac cycle (0.7 second)


(a) ECG
R
P
T
1
Q
4
S
8
0.1 sec
0.3 sec
0.4 sec
Atrial systole
Ventricular systole
Relaxation period
(b) Pressure (mmHg)
120
100
80
60
40
20
0
9 Aortic valve closes
Dicrotic wave
Aortic pressure
6 Aortic valve opens
Left ventricular pressure
5 Bicuspid valve closes
2
10 Bicuspid valve opens
Left atrial pressure
(c) Heart sounds
S1
S2
S3
S4
(d) Volume in ventricle (mL)
130
60
0
3 End-diastolic volume
Stroke volume
7 End-systolic volume
(e) Phases of the cardiac cycle
Atrial contraction
Isovolumetric contraction
Ventricular ejection
Isovolumetric relaxation
Ventricular filling
Atrial contraction

Step 1—*Atrial systole*. This first phase of the cycle begins with the depolarization of the atria (P wave in the ECG). The atria contract. Atrial pressure is greater than ventricular pressure. The AV (mitral) valve opens and blood flows into the ventricle. Ventricular volume increases slightly (this is the end diastolic volume).

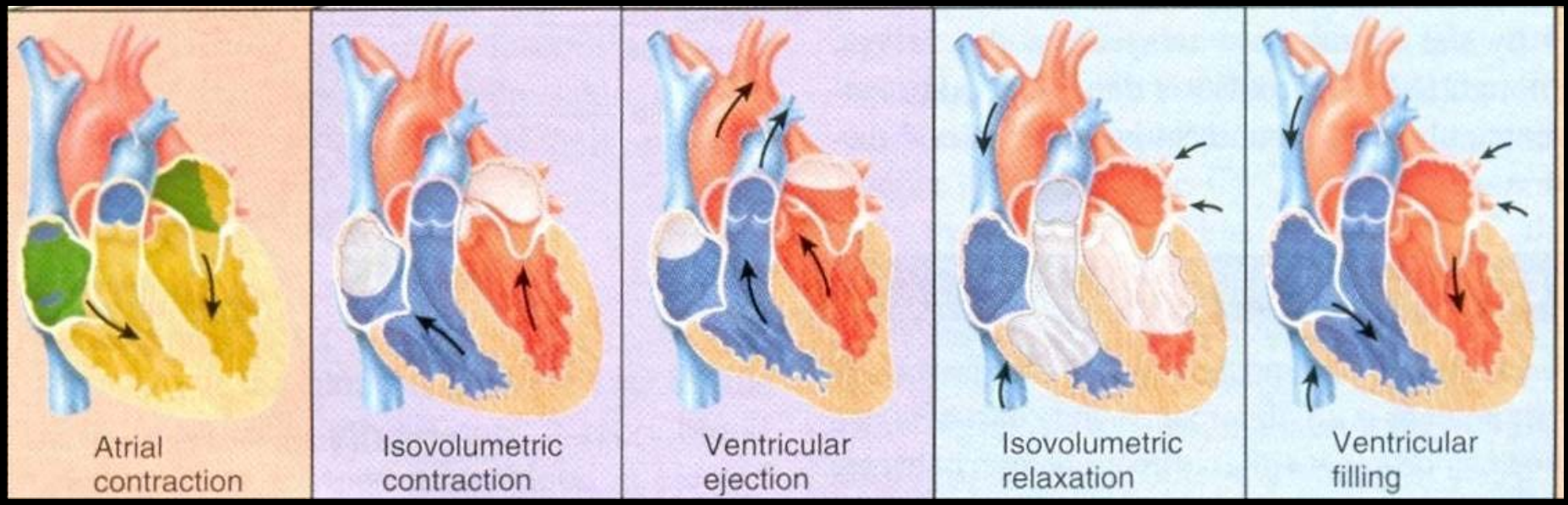
Step 2—*Isovolumetric ventricular contraction (also called early ventricular systole).* This begins with the ventricles depolarizing (QRS complex) then contracting. Ventricular pressure increases rapidly (above atrial but below aortic pressures). The mitral valve closes. No change in ventricular volume.



Step 3—*Ventricular systole (also called ejection period).* The ventricles are still contracting, but now ventricular pressure is above aortic. The aortic valve opens. Blood flows into the aorta, and ventricular volume decreases.

Step 4—*Early ventricular diastole (also called isovolumetric relaxation phase).* Ventricular pressure falls below aortic pressure, and the aortic valve closes. Some blood remains in the ventricles (end systolic volume). Ventricular pressure continues to fall. No change in ventricular volume.

Step 5—*Late ventricular diastole.* Ventricular pressure drops below atrial pressure. The mitral valve opens, and blood flows into the ventricle. Ventricular volume increases. P wave begins, and the cycle repeats.



Atrial Systole

Early Ventricular Systole

Ventricular Systole (Ejection Period)

Early Ventricular Diastole

Late Ventricular Diastole

Contribution of Atrial Contraction to Ventricular Filling

Most of the blood (70–80%) enters the ventricles when they relax (during late ventricular diastole) and not when the atria contract (atrial systole), which contributes roughly 20–30% to ventricular filling. Blood flows passively into the ventricles when the pressure in the atria exceeds that in the ventricles. This pressure gradient begins during late ventricular diastole, when the ventricles are relaxing, and continues until the atria have finished contracting.

Cardiac Cycle—Period of Ejection

In order for blood to be ejected from the heart, the pressure in the ventricles must be greater than the pressure in the aorta. When the pressure in the left ventricle rises above 80 mmHg (which is the pressure in the aorta), the aortic valve opens. Immediately, blood pours out of the ventricles, while the pressure continues to increase to 120 mmHg. The period during which the ventricles empty blood into the aorta is known as the **ejection period.**

DISCLAIMER

- All figures are taken from Guyton and Hall Textbook of Medical Physiology, 12th Edition.