THE CARDIAC CYCLE

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11/13/13

ISOVOLUMETRIC CONTRACTION

The Beginning of systole

11/13/13

ISOVOLUMETRIC CONTRACTION
Heart

- The atrioventricular (AV) valves close at the beginning of this phase.
- Electrically, ventricular systole is defined as the interval between the QRS complex and the end of the T wave (the Q-T interval).
- Mechanically, ventricular systole is defined as the interval between the closing of the AV valves and the opening of the semilunar valves (aortic and pulmonary valves).

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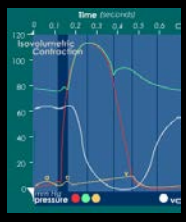
ISOVOLUMETRIC CONTRACTION
Pressures & Volumes



- The AV valves close when the pressure in the ventricles (red) exceeds the pressure in the atria (yellow).
- As the ventricles contract isovolumetrically -- their volume does not change (white) -- the pressure inside increases, approaching the pressure in the aorta and pulmonary arteries (green).

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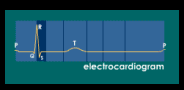
ISOVOLUMETRIC CONTRACTION
ECG



- The electrical impulse propagates from the AV node through the His bundle and Purkinje system to allow the ventricles to contract from the apex of the heart towards the base.
- The QRS complex is due to ventricular depolarization, and it marks the beginning of ventricular systole. It is so large that it masks the underlying atrial repolarization signal. the ventricles to fill completely with blood.

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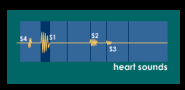
ISOVOLUMETRIC CONTRACTION
Heart Sounds



- The first heart sound (S1, "lub") is due to the closing AV valves and associated blood turbulence.

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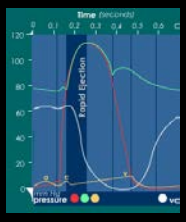
RAPID EJECTION

RAPID EJECTION
Heart

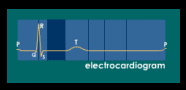
- The semilunar (aortic and pulmonary) valves open at the beginning of this phase.

RAPID EJECTION
Pressures & Volumes



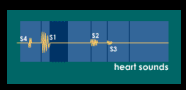
- While the ventricles continue contracting, the pressure in the ventricles (red) exceeds the pressure in the aorta and pulmonary arteries (green); the semilunar valves open, blood exits the ventricles, and the volume in the ventricles decreases rapidly (white).
- As more blood enters the arteries, pressure there builds until the flow of blood reaches a peak.
- The "c" wave of atrial pressure is not normally discernible in the jugular venous pulse. Right ventricular contraction pushes the tricuspid valve into the atrium and increases atrial pressure, creating a small wave into the jugular vein. It is normally simultaneous with the carotid pulse.

RAPID EJECTION
ECG



- No Deflections

RAPID EJECTION
Heart Sounds



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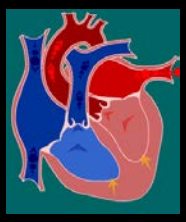
REDUCED EJECTION

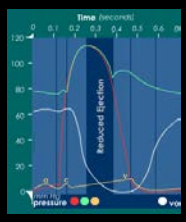
The end of systole

REDUCED EJECTION
Heart



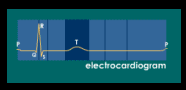
- At the end of this phase the semilunar (aortic and pulmonary) valves close.

REDUCED EJECTION
Pressures & Volumes



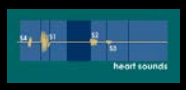
- After the peak in ventricular and arterial pressures (red and green), blood flow out of the ventricles decreases and ventricular volume decreases more slowly (white).
- When the pressure in the ventricles falls below the pressure in the arteries, blood in the arteries begins to flow back toward the ventricles and causes the semilunar valves to close. This marks the end of ventricular systole mechanically.

REDUCED EJECTION
ECG



- The T wave is due to ventricular repolarization. The end of the T wave marks the end of ventricular systole electrically.

REDUCED EJECTION
Heart Sounds



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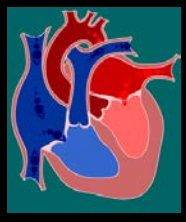
ISOVOLUMETRIC RELAXATION

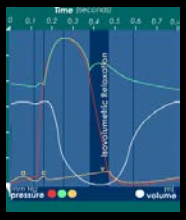
The beginning of Diastole

ISOVOLUMETRIC RELAXATION
Heart



- At the beginning of this phase the AV valves are closed.

ISOVOLUMETRIC RELAXATION Pressures & Volumes



- Throughout this and the previous two phases, the atrium in diastole has been filling with blood on top of the closed AV valve, causing atrial pressure to rise gradually (yellow).
- The "v" wave is due to the back flow of blood after it hits the closed AV valve. It is the second discernible wave of the jugular venous pulse.
- The pressure in the ventricles (red) continues to drop.
- Ventricular volume (white) is at a minimum and is ready to be filled again with blood.

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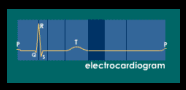
ISOVOLUMETRIC RELAXATION ECG



- No Deflections

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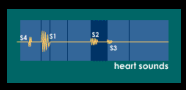
ISOVOLUMETRIC RELAXATION Heart Sounds



- The second heart sound (S2, "dup") occurs when the semilunar (aortic and pulmonary) valves close. S2 is normally split because the aortic valve closes slightly earlier than the pulmonary valve.

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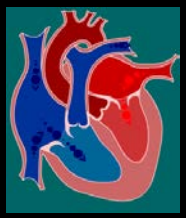
RAPID VENTRICULAR FILLING

11/13/13

RAPID VENTRICULAR FILLING Heart



- Once the AV valves open, blood that has accumulated in the atria flows rapidly into the ventricles.

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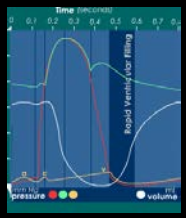
RAPID VENTRICULAR FILLING Pressures & Volumes



- Ventricular volume (white) increases rapidly as blood flows from the atria into the ventricles.

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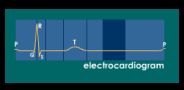
RAPID VENTRICULAR FILLING ECG



- No Deflections

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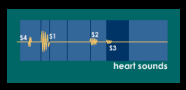
RAPID VENTRICULAR FILLING
Heart Sounds



- A third heart sound (S3) is usually abnormal and is due to rapid passive ventricular filling. It occurs in dilated congestive heart failure, severe hypertension, myocardial infarction, or mitral incompetence.

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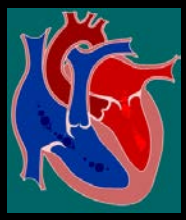
REDUCED VENTRICULAR FILLING

(Diastasis)

11/13/13

REDUCED VENTRICULAR FILLING
Heart



- Rest of blood that has accumulated in the atria flows slowly into the ventricles.

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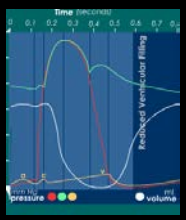
REDUCED VENTRICULAR FILLING
Pressures & Volumes



- Ventricular volume (white) increases more slowly now. The ventricles continue to fill with blood until they are nearly full.

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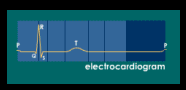
REDUCED VENTRICULAR FILLING
ECG



- No Deflections

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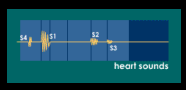
REDUCED VENTRICULAR FILLING
Heart Sounds



- None

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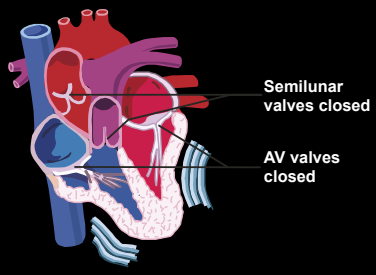
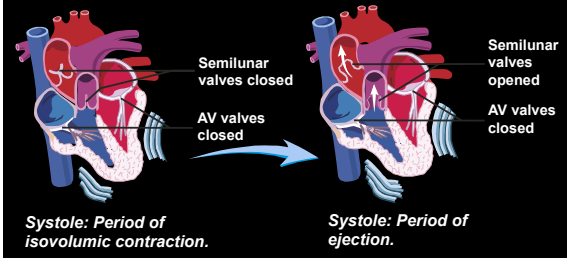
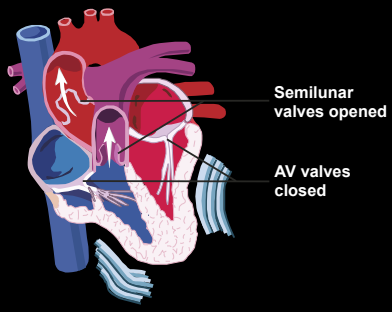


Systole: Period of isovolumic contraction. Ventricular contraction causes the AV valves to close, which is the beginning of ventricular systole. The semilunar valves were closed in the previous diastole and remain closed during this period.

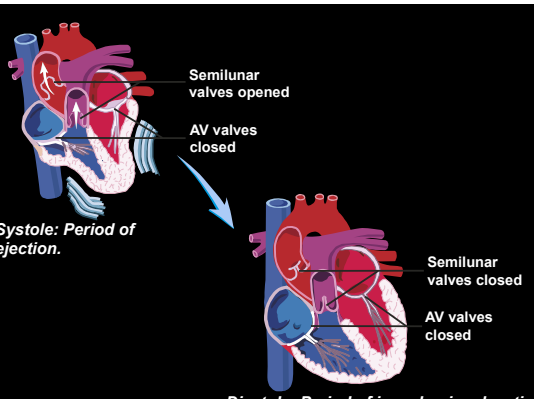


Systole: Period of isovolumic contraction.

Systole: Period of ejection.

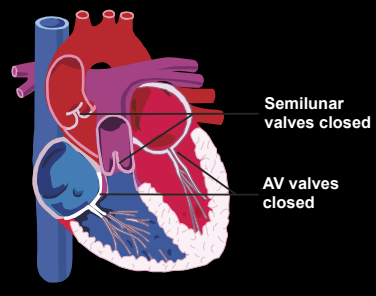


Systole: Period of ejection. Continued ventricular contraction pushes blood out of the ventricles, causing the semilunar valves to open.

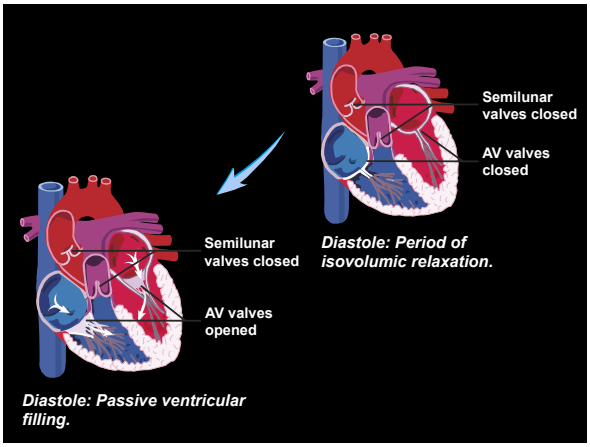


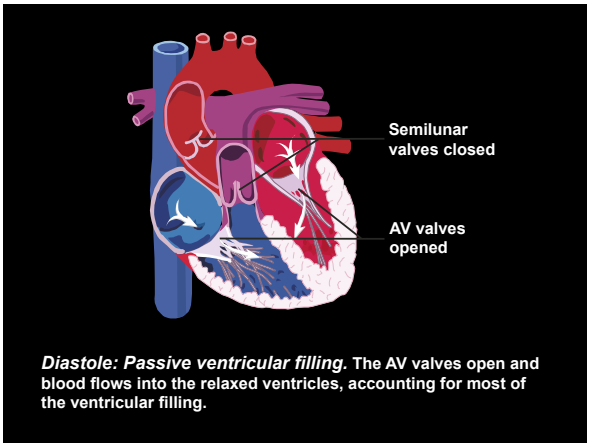
Systole: Period of ejection.

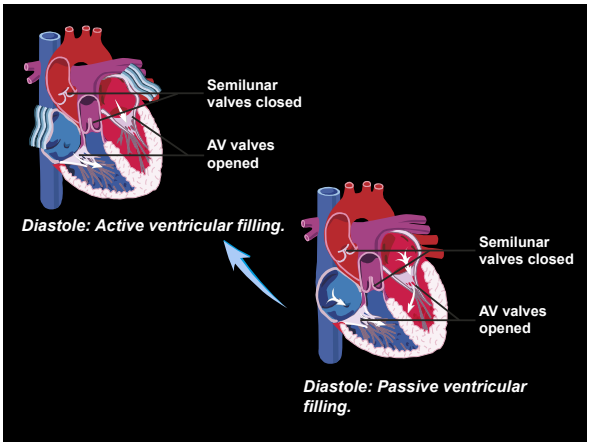
Diastole: Period of isovolumic relaxation.

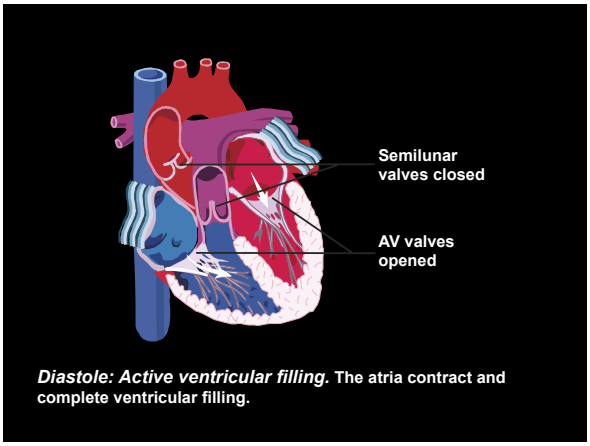


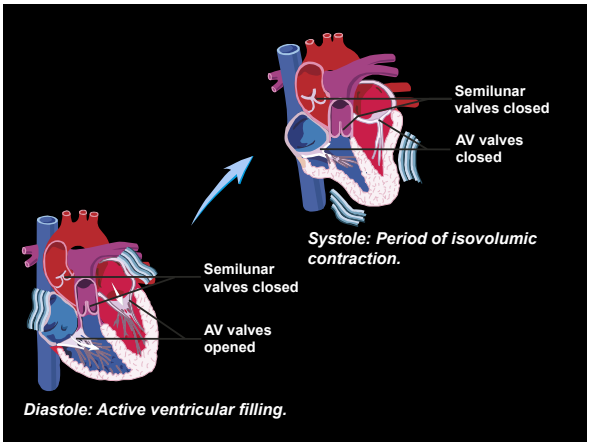
Diastole: Period of isovolumic relaxation. Blood flowing back toward the relaxed ventricles causes the semilunar valves to close, which is the beginning of ventricular diastole. Note that the AV valves closed, also.

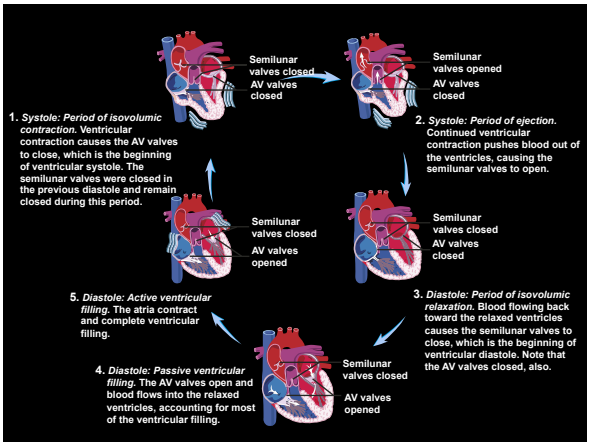

Semilunar valves closed
AV valves closed
Diastole: Period of isovolumic relaxation.
Semilunar valves closed
AV valves opened
Diastole: Passive ventricular filling.


Semilunar valves closed
AV valves opened
Diastole: Passive ventricular filling. The AV valves open and blood flows into the relaxed ventricles, accounting for most of the ventricular filling.


Semilunar valves closed
AV valves opened
Diastole: Active ventricular filling.
Semilunar valves closed
AV valves opened
Diastole: Passive ventricular filling.


Semilunar valves closed
AV valves opened
Diastole: Active ventricular filling. The atria contract and complete ventricular filling.


Semilunar valves closed
AV valves closed
Systole: Period of isovolumic contraction.
Semilunar valves closed
AV valves opened
Diastole: Active ventricular filling.


Semilunar valves closed
AV valves closed
1. Systole: Period of isovolumic contraction. Ventricular contraction causes the AV valves to close, which is the beginning of ventricular systole. The semilunar valves were closed in the previous diastole and remain closed during this period.
Semilunar valves opened
AV valves closed
2. Systole: Period of ejection. Continued ventricular contraction pushes blood out of the ventricles, causing the semilunar valves to open.
Semilunar valves closed
AV valves opened
Semilunar valves closed
AV valves closed
3. Diastole: Period of isovolumic relaxation. Blood flowing back toward the relaxed ventricles causes the semilunar valves to close, which is the beginning of ventricular diastole. Note that the AV valves closed, also.
5. Diastole: Active ventricular filling. The atria contract and complete ventricular filling.
4. Diastole: Passive ventricular filling. The AV valves open and blood flows into the relaxed ventricles, accounting for most of the ventricular filling.
Semilunar valves closed
AV valves opened

Function of the valves

- Valves prevent the back flow of blood.
- The papillary muscles will not close the valves, they will maintain the closure of the valves.
- The importance of chordea tendinei attached to the papillary muscles is because during ventricular contraction the ventricle size decreases and the papillary muscle must contract to shorten the chordea tendinei to prevent the leakage of valves

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Heart sounds

- Listing by a stethoscope to the heart sound we can hear:
- *Lub* (first heart sound) which is associated with the closure of the AV valves
- *Dub* (second heart sound) which is associated with the closure of the semilunar valves

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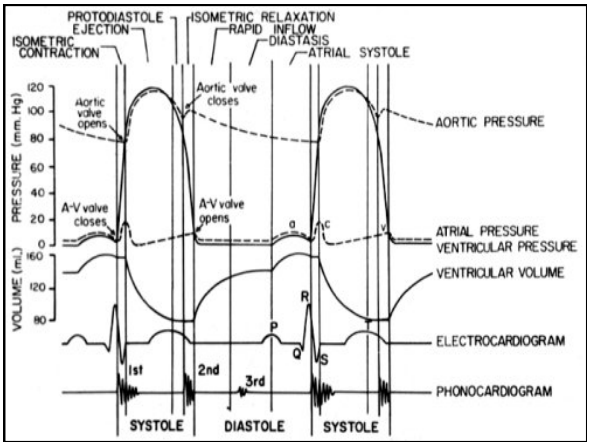

Cause of the heart sounds

- Slapping of the valves leaflets is *not* enough to generate a heart sound.
- The causes of the 1st heart sound:
  - During systole the AV valves are closed & blood tries to flow back to the atrium back bulging the AV valves. But the taut chordae tendinae stop the back bulging and causes the blood to flow forward.
  - This will cause vibration of the valves, blood & the walls of the ventricles which is presented as the 1st heart sound.

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Cause of the heart sounds

- The causes of the 2nd heart sound:
  - During diastole, blood in the blood vessels tried to flow back to the ventricles →cause the semilunar valves to bulge. But the elastic recoil of the arteries cause the blood to bounce forward which will vibrate the blood the valves and the ventricle walls.
  - This is presented as the 2nd heart sound.

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Difference between the 1st and 2nd heart sounds

- The 1st sound lasts longer because the AV valves are less taut than the semilunar valves which will enable them to vibrate for longer time.
- The 2nd heart sound had higher frequency due to
  - The semilunar valves are more taut
  - The great elastic coefficient of the taut arteries which provides the principle vibrations of the 2nd heart sound.

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Other heart sounds

- The 3rd heart sound: is the heard in the mid diastole due to the blood that fills the ventricles.
- The 4th heart sound: also known as atrial heart sound. It occur when the atrium contracts & pumps blood to the ventricles. This sound is almost never heard by the stethoscope.

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Where can we hear the sound?

- *Tricuspid valve*: is best heard at the Rt half the lower end of the sternum body
- *Mitral valve*: is best heard at the Apex of the heart (Lt 5th intercostal space at the mid-clavicular line)
- *Pulmonary valves*: is best heard at the Lt medial 2nd intercostal space
- *Aortic valve* : is best heard in the medial 2nd Rt inetercostal space.

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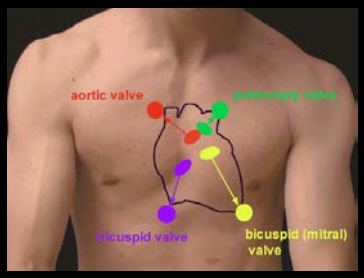
Where can we hear the sound



11/13/13

Heart murmurs caused by valvular lesions

- **Murmurs of the aortic stenosis**

In aortic stenosis, there is narrowing of the aorta →↑resistance to ejection of blood

As a result severe turbulence of blood at the root of the aorta→ intense vibration → loud systemic murmur (after 1st heart sound).

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Heart murmurs caused by valvular lesions

- **Murmur of the aortic regurgitation:**

In aortic regurgitation, the aortic valves doesn' t close which is essential during diastole. Therefore in aortic regurgitation blood backflow in the ventricles causing diastolic murmurs (after the 2nd heart sound).

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Heart murmurs caused by valvular lesions

- **Murmurs of Mitral stenosis**

In mitral stenosis there is narrowing of the mitral valve → increase resistance of blood flow to the ventricles. After 1/3 of diastole when enough blood fills the ventricle, it causes vibration which present as diastolic murmur. The murmur is often not heard but could be felt as thrill at the apex of the heart.

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Heart murmurs caused by valvular lesions

- **Murmurs of Mitral regurgitation**

In Mitral regurgitation the Mitral valves are unable to close which is essential during systole → therefore blood flows back to the atrium causing a systolic murmur.

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Heart murmurs caused by valvular lesions

- **Machinery murmur of patent ductus arteriosis**

In PDA blood flows from the aorta to the pulmonary artery→murmur during systole and diastole. The murmurs during systole is much more tense than in diastole because the pressure in aorta is higher during systole than diastole.

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